NASA/CP–2008-214583 July 2008

Proceedings of the

Next Generation Exploration Conference-2

Entrepreneurial Opportunities in Lunar Development

A gathering of emerging global space leaders to design the future of space exploration

Proceedings of a conference sponsored by the
National Aeronautics and Space Administration
held at NASA Ames Research Center
Moffett Field, California
February 12 - 15, 2008

NASA STI Program...in profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Report Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATIONS. Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATIONS. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include creating custom thesauri, building customized databases, and organizing and publishing reserach results.

For more information about NASA STI program, see the following:

- Access the NASA STI program home page at *http://www.sti.nasa.gov*

- E-mail your question via the internet to help@sti.nasa.gov

- Fax your question to the NASA STI Help Desk at (301) 621-0134

- Phone the NASA STI Help Desk at (301) 621-0390

Write to:
NASA STI Help Desk
NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320

NASA/CP–2008-214583 July 2008

Proceedings of the

Next Generation Exploration Conference-2
Entrepreneurial Opportunities in Lunar Development

Event Organizer:
Jessica Culler
NASA Ames Research Center
Moffett Field, California

Proceedings Editors:
Ken Davidian
NASA Headquarters
Washington, D.C.

Delia Santiago
NASA Ames Research Center
Moffett Field, California

Design & Production:
Julie Fletcher
NASA Ames Research Center
Moffett Field, California

Proceedings of a conference sponsored by the
National Aeronautics and Space Administration
held at NASA Ames Research Center
Moffett Field, California
February 12 - 15, 2008

Table of Contents

Speakers' Presentations

Working Group Reports

Appendices

OVERVIEW

As humanity reaches out to explore and understand the universe surrounding us, the Earth's Moon stands as the first natural stepping stone away from our home planet. Nearly four decades after mankind first touched its surface, it remains largely unexplored and unutilized. However, technology has continued to develop, making Lunar activities feasible for commercial as well as government entities. Now, a renewed emphasis on space exploration beyond the Moon has created incentives to both utilize the Moon in achieving these exploration goals and involve private business to reduce cost and facilitate Lunar activities.

With this in mind, the second Next Generation Exploration Conference (NGEC-2) brought together emerging space leaders for a four-day workshop of collaboration and strategy development.

More than 100 hand-selected future leaders in the space sector met at NASA Ames Research Center February 12–15, 2008, to gather information, exchange ideas, and brainstorm in working groups to create an output that will offer global guidance on the topic of Entrepreneurial Opportunities in Lunar Development. This next generation of leaders, along with virtual contributors participating through NASA CoLab and Second Life, included engineers, scientists, and communication specialists from the United States and abroad, both industry and government.

Attendees at NGEC-2

100 young space professionals
Average age 28
24 % International
Countries(8)—Australia, Austria, Canada, Honduras, Norway, Pakistan, Switzerland, United States

A New Way of Conferencing
The invitation-only event gathered emerging space leaders with technical talents applicable to the conference theme. Participation, however, was extended beyond the usual means of attendance and in-person contribution.

Conference participation initiated prior to the in-person gathering was facilitated by NASA CoLab's conference facilitation tool, at http://nasacolab.org. This tool allowed for significant dialogue prior to the actual event, thus maximizing the output of the time in person. The conference facilitation tool also supported user-generated conference content by allowing conference participants to propose conference sessions and vote on the ones they thought would be of most value. In addition to the in-person and online components of the conference, additional involvement was facilitated via Second Life, a publicly virtual world where NASA CoLab has established a presence. This virtual world allowed people not physically present to listen to presentations and engage in the dialogue. Second Life participants submitted questions to conference presenters via liaisons present at the conference and also logged into Second Life. A full report on the Second Life component of NGEC-2 is included in Appendix A of this proceedings document.

Conference Intent

The second Next Generation Exploration Conference (NGEC-2) was supported by the Exploration Science Mission Directorate (ESMD) and Innovative Partnerships Program (IPP) at NASA Headquarters. The ESMD Commercial Space Development Policy (ECMD) and the ECMD Implementation Plan were used as guidelines for the types of entrepreneurial opportunities to be identified at the conference. NASA's 2006 Strategic Plan states that NASA shall encourage the development of the commercial space sector. The goal was for participants to:

- Identify and analyze entrepreneurial opportunities for commercial space capabilities that expand the Earth's economic sphere of influence out to and including the Moon.
- Help shape and design the future of the space program.
- Produce a document to be used by current and future generations of explorers.

Conference Scope

NGEC-2 participants looked at services and technologies that NASA and other space agencies could sell to private businesses as they venture into the Lunar realm. The delegates also considered products and services provided by private companies that would enable Lunar development, but could also provide a profit by addressing underserved markets on Earth. These potential products and services fell into five broad categories as they pertained to Lunar activities:

- Infrastructure, Utilities, and Consumables
- Services
- Lunar Access
- Lunar Environment Utilization
- Cultural Industries

Working groups were dedicated to each of these categories. They identified specific entrepreneurial opportunities for each category, as well as the time frame over which that opportunity is expected to become feasible. The groups identified the near-term ideas with the highest likelihood of profitability, and applied some initial market analysis. The results of their research and collaboration are compiled herein. It is hoped that this document can provide a starting point for innovative businesses as they begin to advance into the realm of Lunar operations, thereby giving the private sector and all of humanity a further foothold into space.

Conference Results

The full results from each working group are included in this document. The body text includes discussion and details for the items identified as special areas of imminent opportunity. The full list from each group can be found in Appendix A. Appendices B and C concentrate on the near-term opportunities only.

Since the commercial opportunities identified as "near-term" are given focus, each one has been given an identification code to identify them across the different locations in which they appear in text and tables. Each opportunity code consists of a letter representing the working group which identified it and a sequential number.

I – Infrastructure, Utilities, and Consumables
S – Services
A – Lunar Access

E – Lunar Environment Utilization
C – Cultural Industries

Appendix A contains the Time-Phase Analysis Table, which shows all the ideas that each working group identified as commercial opportunities for Lunar development put into categories of near-term (less than 10 years), mid-term (10-20 years), and far-term (20-30 years).

Appendix B contains the Market Analysis Table, listing the near term commercial opportunities for Lunar development, and identifying the following for each row: (a) what the U.S. Government (including NASA) plan is to provide these items; (b) what the U.S. Government (including NASA) demand for these items is thought to be; (c) what (if any) private entities exist that might be able to supply the identified item; and (d) what (if any) private entities exist that might have a demand for the item. A final column is included that lists any identified risks that each item may possess.

Appendix C contains a list of risks associated with each of the near-term commercial opportunities identified and the policy recommendations of each group.

ESMD INTRODUCTION

It was my pleasure to be a part of the second Next Generation Exploration Conference (NGEC-2) that was conducted at the NASA Ames Research Center on February 12-15, 2008. I had the distinct pleasure of being able to direct the activities so the Conference deliverables were planned to closely align with the Exploration Systems Mission Directorate (ESMD) Commercial Development Policy and Implementation Plan in potential new Lunar commercial markets.

The direction given the conference attendees follows:

- Identify potential industry sector commercial activities by reviewing past writings on Lunar commercial development ideas, including results of the Global Exploration Strategy (multiple meetings conducted in 2006 by the NASA Exploration Systems Mission Directorate) and all ideas gleaned from the pages of other writings, including the Moon Miners' Manifesto (documents that span 30 years of activity) and the Artemis Project Databook. These latter documents contain a large quantity of structured thinking on this subject.
- Add to the list of potential industry sector commercial activities by brainstorming new ideas. Items on this list can be as general as identification of an entire industry sector (e.g., oxygen generation and supply) or as specific as to include narrative descriptions of a business plan idea (e.g., description of a little roving machine that consumes regolith and deposits liquid oxygen stored in iron bottles, both of which are extracted from the regolith).
- Apportion the activity ideas into categories of how much time they think will be needed to make this activity a reality: near-term (e.g., 0–10 years), midterm (10–20 years), or far-term (>20 years). Of course, the definitions of the time phasing can be changed by group consensus.
- Starting with the near-term potential industry sector commercial activity ideas, identify the following:
  - Is there now, or will there be a NASA need/demand for this activity? If so, what is it?
  - Are there now, or will there be NASA-supplied capabilities (government-supplied goods or services) to meet this need/demand?
  - Is there now, or will there be a private (non-government) need/demand for this activity? If so, who needs it?
  - Are there now, or will there be private (non-government) supplied capabilities (supplied goods or services) to meet the need/demand?

I am proud of the results of the working groups and the collaborative effort of the conference attendees in general. This report will be a useful and powerful tool to promote new commercial development activities within NASA.

Ken Davidian
Lead, Commercial Development Policy
Exploration Systems Mission Directorate
NASA Headquarters

IPP FOREWORD

The Innovations Partnership Program Office co-sponsored the NGEC-2 conference. When we heard that there was an opportunity to gather over 100 young space professionals from around the world to engage in meaningful discussions and brainstorming of ideas on NASA exploration, we knew we wanted to be a part of the event. It was quite unusual to see this many young people truly excited about the possibilities of lunar exploration and so willing to immerse themselves in the exercises.

One of the truly unique things about the NGEC-2 conference was that it could be described as an output-generation event. Whereas most conferences are set up for the attendees to sit, soak in information, take notes, possibly provide minimal feedback at the end of the conference, and then go home, this conference was designed for maximum participation and product creation. The working groups spent hours each day developing their products, and even went late into each night further sharing ideas and discussing the "what if's" with other attendees.

Buzz Aldrin's talk about his historical experiences as well as his current ideas for space exploration was a particular highlight of the conference. Just being in the presence of a man who actually walked on the moon was an inspiration to all who were lucky enough to be in the audience. However when Buzz took the time to personally speak with and listen to the attendees afterwards, it was a memorable if not life-changing experience for many.

The motivations and design criteria for Lunar exploration have changed greatly since those early years, but the zeal for Lunar exploration is apparently undiminished almost 40 years after that first Moon walk. Seeing this next generation of space explorers commit their time and energy into working with NASA is exciting. I believe these conferences are very important to NASA by providing us with new ideas, new communication tools, new windows into public perceptions, new partners, and a huge source of space professionals willing to get personally involved to solve the hard problems of space exploration.

Y. Diane Powell
Innovative Partnerships Program
NASA Headquarters

EXECUTIVE SUMMARY

More than 100 young space professionals from 8 countries met at NASA Ames Research Center February 12–15, 2008, with the support of NASA's Exploration Systems Mission Directorate and the Innovative Partnerships Program. The participants, including engineers, scientists, and communication specialists, addressed 5 areas of Entrepreneurial Opportunities in Lunar Development: Infrastructure, Utilities, and Consumables; Services; Lunar Access; Lunar Environment Utilization; and Cultural Industries.

Infrastructure, Utilities, and Consumables
"Infrastructure" is a broad term referring to all physical capital that enables Lunar development. The "consumables" are the items that are required for development and sustainability of a Lunar community (i.e., water, fuel, and oxygen). Future Lunar operations will benefit if they can draw upon a foundation of infrastructure, utilities, and consumables that have previously been established. This infrastructure will reduce mission cost and allow for longer mission durations. With regard to Utilities and Consumables, near-term areas for focus include orbital habitation research and development, autonomous robots, co-development of power-storage technology, Earth-based research for general materials testing for infrastructure, life support systems technology with terrestrial applications, solar energy with Earth-based markets, ground stations for communication networks, and pattern-recognition software for various Lunar applications.

Services
The Services working group identified existing services that are terrestrial analogs to those required during Lunar development. These analogs have the common elements of international cooperation, industry-driven standardization, and open labor markets. It defined "service" as the continuous provision of labor, space, or equipment useful to others. A commercial service opportunity has an additional value proposition for stakeholders.

Near-term areas for focus include preventive and telemedicine services; communication management and regulation to, from, and on the Moon; legal advice regarding space law and Lunar property issues; financial services such as insurance; operational support including emergency services and knowledge stores; development of industry standards; utilities management; waste management; and navigation services.

Lunar Access
Lunar access is a key element to commercial development of the Moon. Lunar mission designs have been studied for a long time, including orbital mechanics, navigation and guidance systems, and travel from launch to low Earth orbit (LEO) using Lagrangian point to Lunar insertion orbit to Lunar landing, and then back to Earth. To date, a few industries have looked at possible commercialization of segments involved in Lunar access, including the commercial development of the systems, vehicles, and services required to transport crew and cargo from the Earth to the Moon and all points in between.

Near-term areas for focus include commercial test services and technology enablers for small Lunar landers, a multiple-lander U.S. Evolved Expendable Launch Vehicle (EELV) Secondary

Payload Adapter ring ("ESPA ring") to enable deploying landers at various time intervals, secondary payload Earth-to-orbit launch vehicle adapters, an (unmanned) spacecraft tug, an (unmanned) spacecraft ferry between various places, automated rendezvous and docking technologies and adaptors, and orbital propellant depots.

Lunar Environment Utilization
In situ resource utilization (ISRU) has a long history of research, particularly following the return of Lunar regolith brought back to Earth by Apollo astronauts.

The Lunar environment offers multiple opportunities for resource usage. While the scientific merits of such utilization are worthy on their own, successful, realistic exploitation will depend significantly on commercially viable enterprises, including volatiles, metals, and dust grains themselves. The physical properties of the Lunar regolith, its abrasiveness, and its natural protection against solar irradiation can also be addressed with entrepreneurial twists. Near-term areas for focus include Lunar map production for scientific, educational, and resource prospecting purposes; space-ruggedized instrumentation, tool, and equipment research and development; and the selling of Lunar dust for both research and novel, niche industries.

Cultural Industries
This group examined and identified entrepreneurial activities that inspire interaction among people, societies, and technology as we move off the planet towards the Moon and beyond. Extending human civilization to other terrestrial worlds, including the Moon, will see the birth of cultural industries unique to both the Moon and extensions of Earth culture. Aiding commercial activity in cultural industries would be helpful for fulfilling NASA's education and outreach initiates, and would have a cultural impact that is necessary for expanding the global economy to the solar system. NASA can sell the importance of considering future Lunar cultural industries on the basis of education and outreach.

Near-term areas of focus include partnership initiation for a Superhero Experience similar to space tourism, space-themed reality television shows with terrestrial beginnings, a "Lonely Moon" travel guide, Cirque de Lune with terrestrial beginnings, space-jewelry development, Lunar data archiving solicitations, and a space public relations agency.

Participant List

First name	Last name	Organization	Citizenship
Trinity	Allen	NASA Ames Research Center / Education Associates	USA
Kelley	Atkinson	NASA Jet Propulsion Laboratory	USA
Tim	Bailey	Sky Fire Lab	USA
Jennifer	Bailey	USAF	USA
Alex	Baklashov	Space Portal	USA
Gwen	Barnes	Carl Sagan Center, SETI Institute	USA
Melissa	Battler	University of Western Ontario’s Planetary Science Research Group	Canadian
Julie	Bellerose	University of Michigan	Canadian
Marshal	Blessing	Raytheon - Space and Airborne Systems	USA
Grant	Bonin	University of Toronto Space Flight Laboratory	Canadian
Chris	Boshuizen	Space Generation Advisory Council	Australian
Aisha	Bowe	University of Michigan	USA
Michael	Brett	Loktar Systems	Australia
Stephen	Broschart	NASA Jet Propulsion Laboratory	USA
Laura	Burns	NASA Goddard Space Flight Center	USA
Kerri	Cahoy	Space Systems/Loral / Stanford University	USA
Jeffery	Candiloro	Astra Australis	Australia
Christian	Carpenter	Aerojet	USA
Frank	Centinello	University at Buffalo	USA
A.C.	Charania	SpaceWorks Engineering, Inc.	USA
Julie	Chittenden	Arkansas State University	USA
Natacha	Chough	University of Michigan Medical School	USA
Kimberley	Clayfield	Space Licensing and Safety Office	Australian
Kevin	Clinton	NASA Kennedy Space Center	USA
Thomas	Coffee	MIT	USA
Amy	Connors	Stellar Solutions	USA
Jessy	Cowan-Sharp	NASA Ames Research Center	Canada
Jessica	Culler	NASA Ames Research Center	USA
Daphne	Dador	California Space Authority	USA
Matt	Daniels	NASA Ames Research Center	USA
Laurie	Darling	NASA Johnson Space Center	USA
Jay	Dedman	http://ryanishungry.com	USA
Dai	Dinh	SJSU - ACES	USA
Jacques	Dolan	Carnegie Mellon University	USA
Shuonan	Dong	NASA Jet Propulsion Laboratory / MIT	USA
Randall	Echevarria	California Space Authority	USA
J.R.	Edwards	Lockheed Martin	USA
Daniel	Faber	Heliocentric Technologies Inc.	Australia
Talmon	Firestone	NSD-Fusion GmbH / Consortium Neutron Systems	Canadian
Garret	Fitzpatrick	NASA Johnson Space Center	USA
Susan	Fonseca-Klein	Kurzweil Technologies Inc.	USA/other
Trevor	Foster	Empirical Systems Aerospace, LLC	USA
Bryan	Gardner	M.I.T.	USA

PARTICIPANT LIST

First name	Last name	Organization	Citizenship
Jonathan	Goff	Masten Space Systems	USA
Andrew	Gold	Advanced Wireless Communications	USA
Paul	Graham	4Frontiers Corporation	USA
Sara	Hatch	NASA Jet Propulsion Laboratory	USA
Jonathan	Hofeller	Space Exploration Technologies	USA
Andrew	Hoppin	NASA Ames Research Center	USA
Sharon	Jefferies	NASA Langley Research Center	USA
Stephen	Jeffress	NASA Kennedy Space Center	USA
Tamra	Johnson	Northrop Grumman Space Technology	USA
John	Karcz	SETI Institute	USA
Zahra	Khan	Massachusetts Institute of Technology	Canada, Pakistan
Bruce	Klein	Kurzweil Technologies Inc.	USA
Cassie	Kloberdanz	University of Colorado	USA
Chisato	Kobayashi	Spacevoke, Ltd.	Japan
Ryan	Kobrick	University of Colorado at Boulder	Canada & USA
Amaresh	Kollipara	Earth2Orbit, LLC	USA
Trond	Krovel	Lunar Explorers Society	Norwegian
Matt	Lacey	NASA Kennedy Space Center / Johnson Space Center	USA
Ashwin	Lalendran	University of Michigan	US Perm. Resident, Canadian citizen
Rivers	Lamb	NASA Goddard Space Flight Center	USA
Michael	Lamberty	NASA Academy Alumni Association	USA
Karen	Lau	ºLau Design Lab/AstraCultura	USA
Ryan	Lefkofsky	NASA Dryden Flight Research Center	USA
Richard	Leshner	NASA Headquarters	USA
Michael	Lindsay	University of Michigan	USA
Adam	London	Ventions, LLC	USA
Alex	MacDonald	NASA Ames Research Center / University of Oxford	Canadian
Marianne	Mader	Carleton University	Canada
Jessica	Marquez	NASA Ames Research Center	USA
Patrick	Mellody	Harmony Consulting	USA
Greg	Mindorff	Titan Sound	Canada
Sean	Mobilia	SJSU - ACES	USA
Chris	Nelson	Oceaneering Space Systems	USA
Karyl	Newman	Chandler and Menouche	USA
Joseph	Palaia	4Frontiers Corporation	USA
Rocky	Persaud	Interplanetary Expeditions Inc.	Canada
Brandt	Pyles	Northrop Grumman Space Technology	USA
Matthew	Reyes	Exploration Solutions, Inc.	USA
Aaron	Rowe	University of California Santa Barbara	USA
Benjamin	Sanders	Pole 2 Pole	Canada
Delia	Santiago	NASA Ames Research Center	USA
Josh	Scherbenski	NASA Jet Propulsion Laboratory / NASA Headquarters	USA
Robert	Schingler	NASA Ames Research Center	USA
Michael	Schoen	Orbital Sciences Corporation	USA

First name	Last name	Organization	Citizenship
Brian	Schoening	Northrop Grumman	USA
Florian	Selch	Carnegie Mellon University	Austria
Jonathan	Sheffield	Space Systems/Loral	USA
Nicholas	Skytland	NASA Johnson Space Center	USA
Sanjoy	Som	University of Washington	Switzerland
Justin	Thomas	United Space Alliance	USA
Erin	Tranfield	NASA Ames Research Center	Canadian
Andy	Turner	Space Systems/Loral	USA
Ezinne	Uzo-Okoro	NASA Goddard Space Flight Center	USA
Graylan	Vincent	NASA Academy Alumni Association	USA
Mary Beth	Wilhelm	NASA Ames Research Center	USA
Steve	Wilson	NASA Johnson Space Center	USA

Tuesday, February 12, 2008

09:30-10:00	Welcome by NASA Ames Center Director *Pete Worden, Ames Center Director*
10:00-10:30	NASA Ames History Presentation by *Jack Boyd, Senior Advisor to the Ames Center Director*
10:30-13:00	Tours of NASA Ames
13:00-14:30	Lunch
14:30-15:30	Exploration in Action with *Keith Cowing, SpaceRef Interactive, Inc.* and *Matthew Reyes, Exploration Solutions, Inc.*
15:30-16:00	Science vs. Exploration Discussion | | Introduction to NASA
16:00-16:30	Constellation Program Overview and Lunar Architecture *Richard Leshner, International Partnerships Lead Exploration Systems Mission Directorate, NASA Headquarters*
16:30-17:00	Previous Commerical Architecture Studies *Ken Davidian, Lead Commercial Development Policy, Exploration Systems Mission Directorate, NASA Headquarters*
17:00-17:30	Current NASA Commercial Development Policy and Previous Approaches *Ken Davidian, Lead Commercial Development Policy, Exploration Systems Mission Directorate, NASA Headquarters*
18:00-18:30	Town Hall Discussion for NGEC-2
19:00-21:00	Director's Reception

Wednesday, February 13, 2008

09:00-09:30	Coffee & Breakfast + *STS-120 crew visit*
09:30-10:00	Opening Keynote - *Dr. Gale Allen, Director (acting), Strategic Integration and Management, ESMD, NASA HQ*
10:00-12:30	Working Group Breakout (Goal: Work plan for rest of conference and subgroup breakouts)
12:30-13:30	Lunch Plenary - *Chris Kemp, NASA ARC CIO*
13:30-15:00	Working Group Breakout (Goal: Perform Market Analysis and Time-Phasing Analysis)
15:00-17:00	Working Group Breakout

17:00-18:00	Working Groups Lightning Presentations
18:00-21:00	"New Space Professionals - Tomorrow's Workforce" Reception and Dinner presented by the *California Space Authority*
21:00-21:30	Gen Y Perspectives
21:30-00:00	Late Working Session: "Communicating Exploration" with *Gary Martin, Director of New Ventures and Communication, NASA ARC*

Thursday, February 14, 2008

09:00-10:30	Coffee & Breakfast + *Buzz Aldrin* visit
10:30-12:30	Working Group Breakouts (Goal: Perform market analysis and time-phasing analysis; populate final documents)
12:30-13:30	Lunch Plenary - *Taber MacCallum, CEO/Chairman of the Board, Paragon Space Development Corporation*
13:30-15:00	Working Group Breakouts (Goal: Identify enabling actions by government agencies, industry, and academia; create proceedings distribution plan identifying audiences and potential partnerships)
15:00-17:00	Working Group Breakouts
17:00-18:00	Working Groups Lightning Presentations
18:00-20:00	Young @ Heart NASA Networking Event
21:00-24:00	Late Working Sessions: Next Gen Space Entrepreneurs, Enabling Technologies for Lunar and Mars Access and Habitation, Young Professional Space Groups, Open Presentations

Friday, February 15, 2008

09:00-09:30	Coffee + Breakfast
09:30-10:30	Speaker - *Robert Richards, Odyssey Moon Limited Founder*
10:30-12:00	Working Group Breakout
12:00-14:00	Lunch / Presentations from Each Group
14:00-14:30	Closing Keynote - *Doug Comstock, Director Innovative Partnerships Program Office, NASA HQ*
16:30	Future Next Gen Community Planning

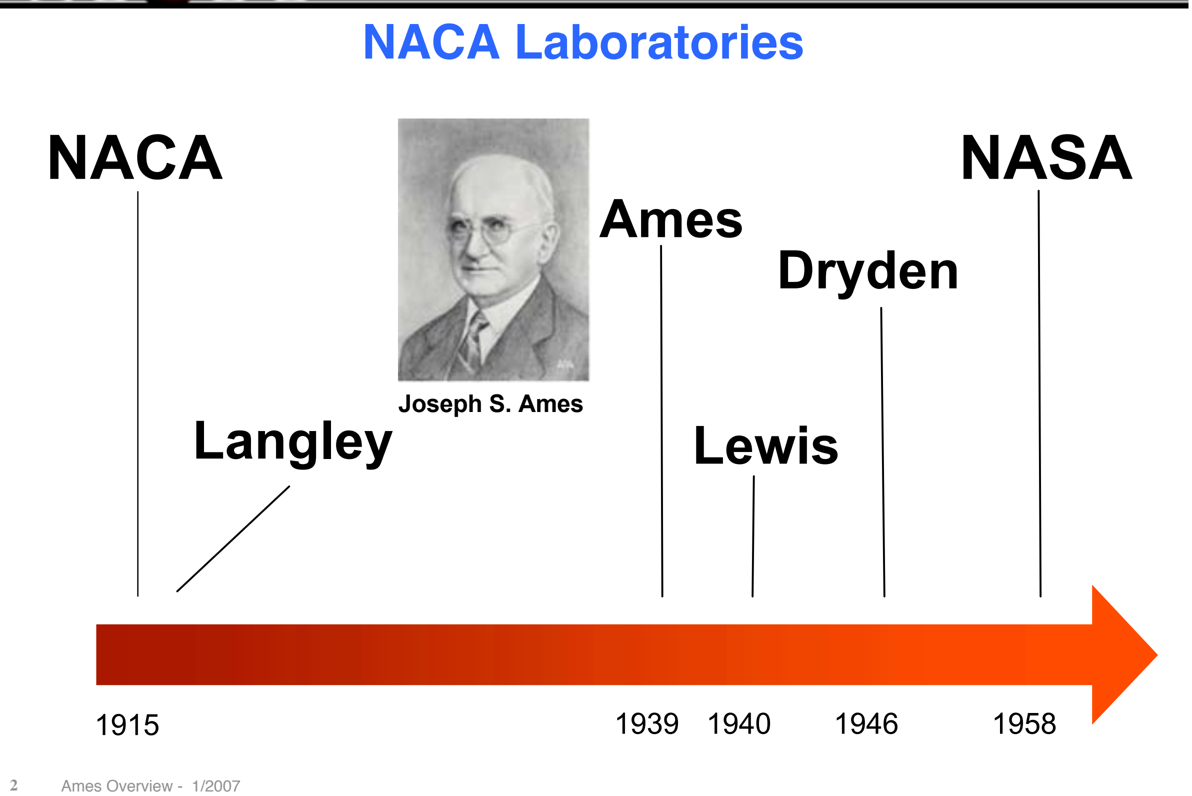
NGEC-2 Speaker Presentations

Jack Boyd *NASA Ames Research Center*

John W. (Jack) Boyd was recently brought back as the Senior Advisor to the Ames Center Director. Prior to this position he was the Ames Historian and the Ombudsman for the Center. As the official historian, Mr. Boyd captured important historical information for future publications concerning significant research accomplishments of this Center. Previous to this position, he was the Executive Assistant to the Director at NASA Ames Research Center for over 8 years. Mr. Boyd began his career at Ames in 1947, when it was still the National Advisory Committee for Aeronautics (NACA) Ames Aeronautical Laboratory, and worked as an aeronautical research engineer conducting wind tunnel studies of the supersonic and subsonic characteristics of fighter/bomber aircraft. He later pioneered early research on the design of unmanned planetary probes to explore Mars and Venus, and helped develop early configurations for the Mercury, Gemini, and Apollo capsules, as well as the space shuttle design. He is a graduate of George Washington High School in Danville, Virginia, Virginia Tech; and Stanford University.

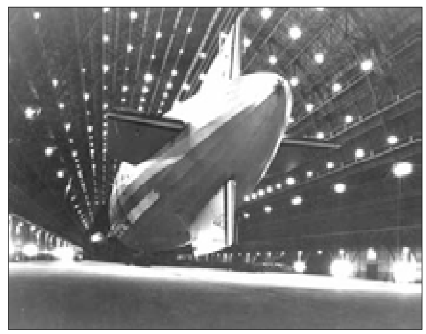
Mr. Boyd has served as Deputy Director of Dryden Flight Research Center, Deputy and Associate Director of Ames Research Center, and Associate Administrator for Management at NASA Headquarters. Additionally, he was also chancellor for Research for The University of Texas System. He has also been an adjunct professor at The University of Texas (Austin, El Paso, and Pan American campuses) teaching courses in aerodynamics, introduction to engineering, and the history of space flight.


NASA Ames Research Center Overview
Next Generation Exploration
Conference - II
February 12, 2008
John W. Boyd, Senior Advisor to Director
NASA Ames Research Center in Silicon Valley
Ames Research Center in Silicon Valley


NACA Laboratories
NACA
NASA
Ames
Dryden
Langley
Lewis
Joseph S. Ames
1915
1939
1940
1946
1958
2
Ames Overview - 1/2007

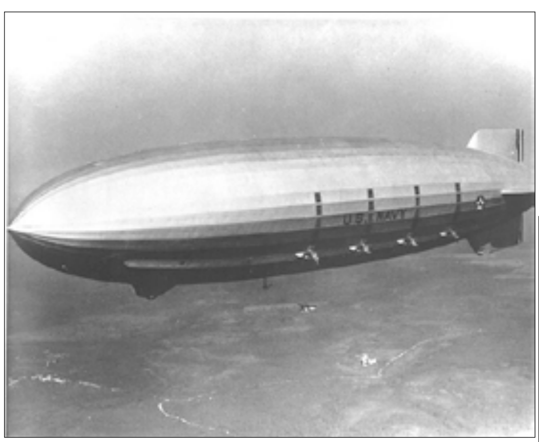
Ames Research Center *in Silicon Valley*

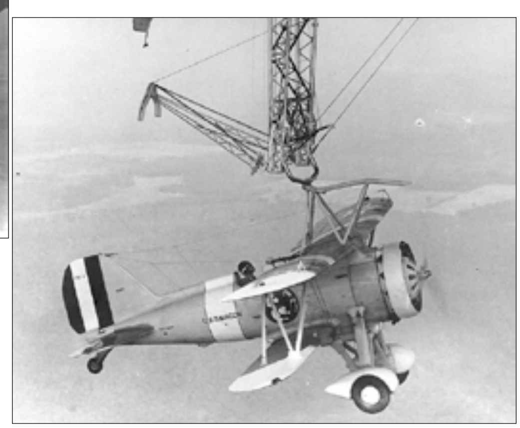
1934 Macon & Hangar 1



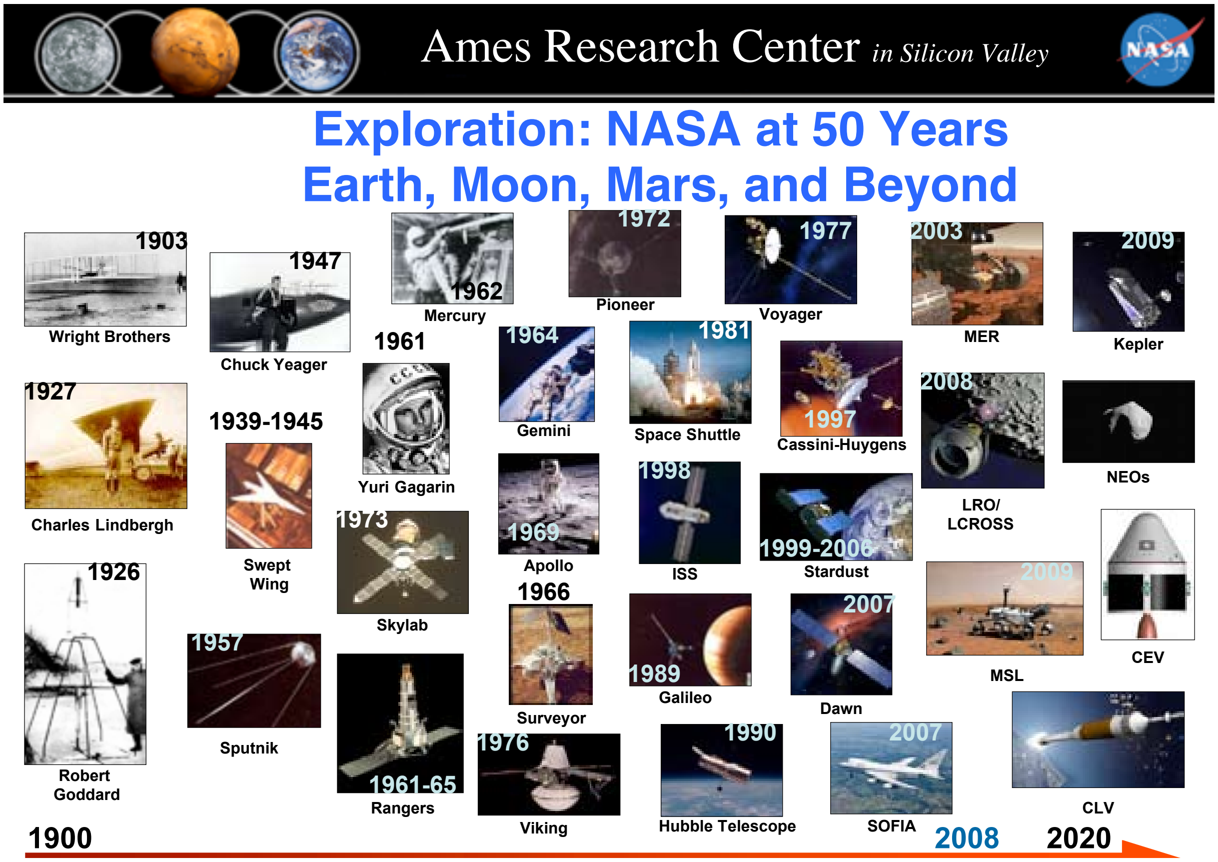
Ames Research Center *in Silicon Valley*

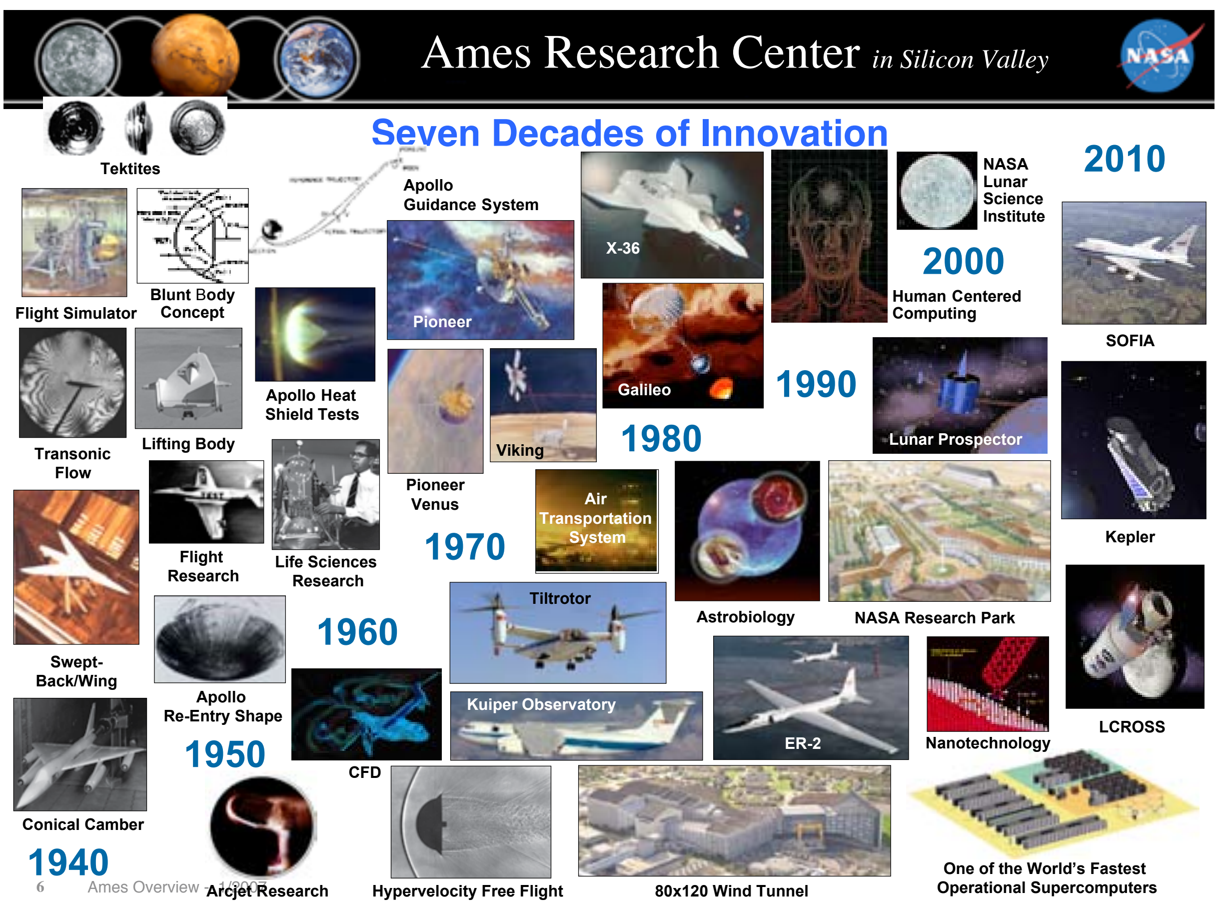
1934 Macon & Sparrowhawk





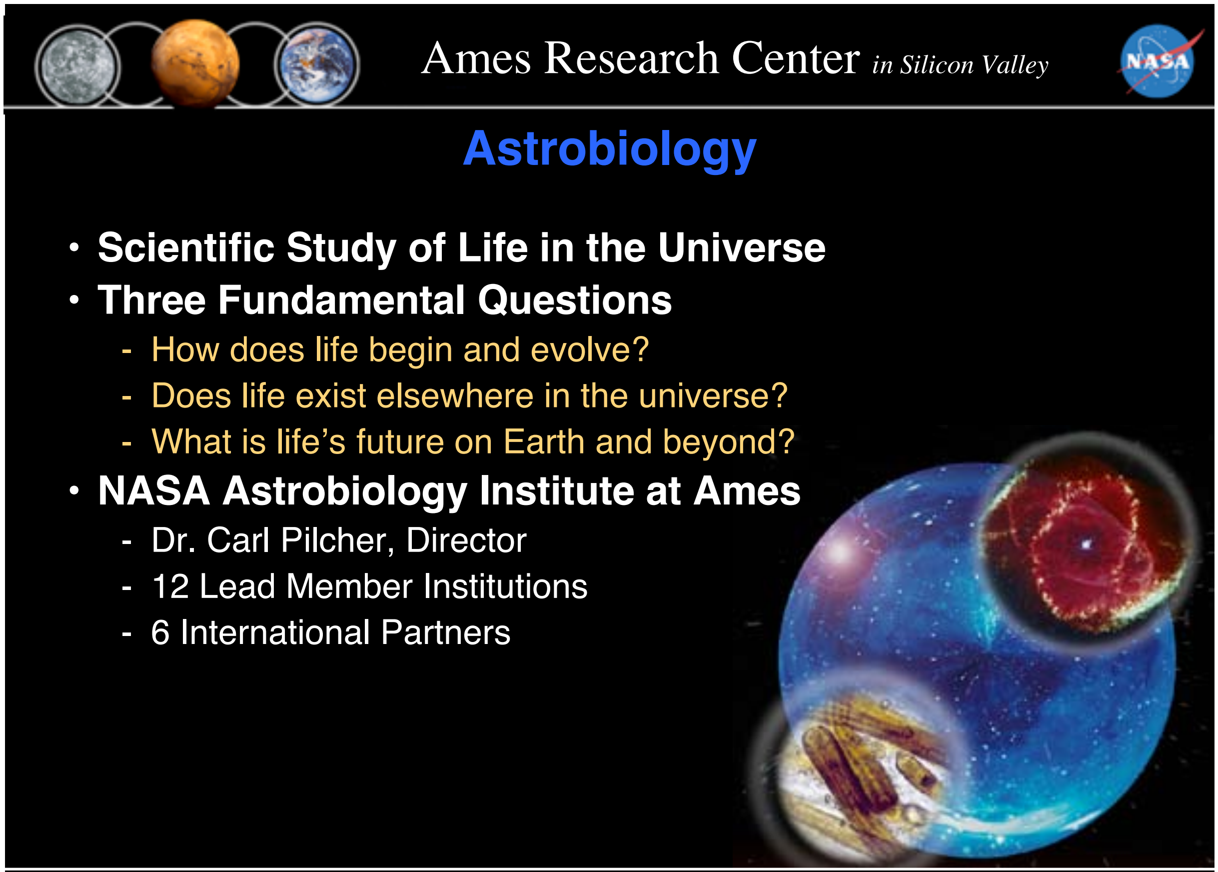
4 Ames Overview - 1/2007


Ames Research Center in Silicon Valley
NASA
Exploration: NASA at 50 Years
Earth, Moon, Mars, and Beyond
1903
Wright Brothers
1947
Chuck Yeager
1962
Mercury
1972
Pioneer
1977
Voyager
2003
MER
2009
Kepler
1961
Yuri Gagarin
1964
Gemini
1981
Space Shuttle
1997
Cassini-Huygens
2008
LRO/
LCROSS
NEOs
1927
Charles Lindbergh
1939-1945
Swept
Wing
1973
Skylab
1969
Apollo
1998
ISS
1999-2006
Stardust
2009
MSL
CEV
1926
Robert
Goddard
1957
Sputnik
1966
Surveyor
1989
Galileo
2007
Dawn
1961-65
Rangers
1976
Viking
1990
Hubble Telescope
2007
SOFIA
CLV
1900
2008
2020

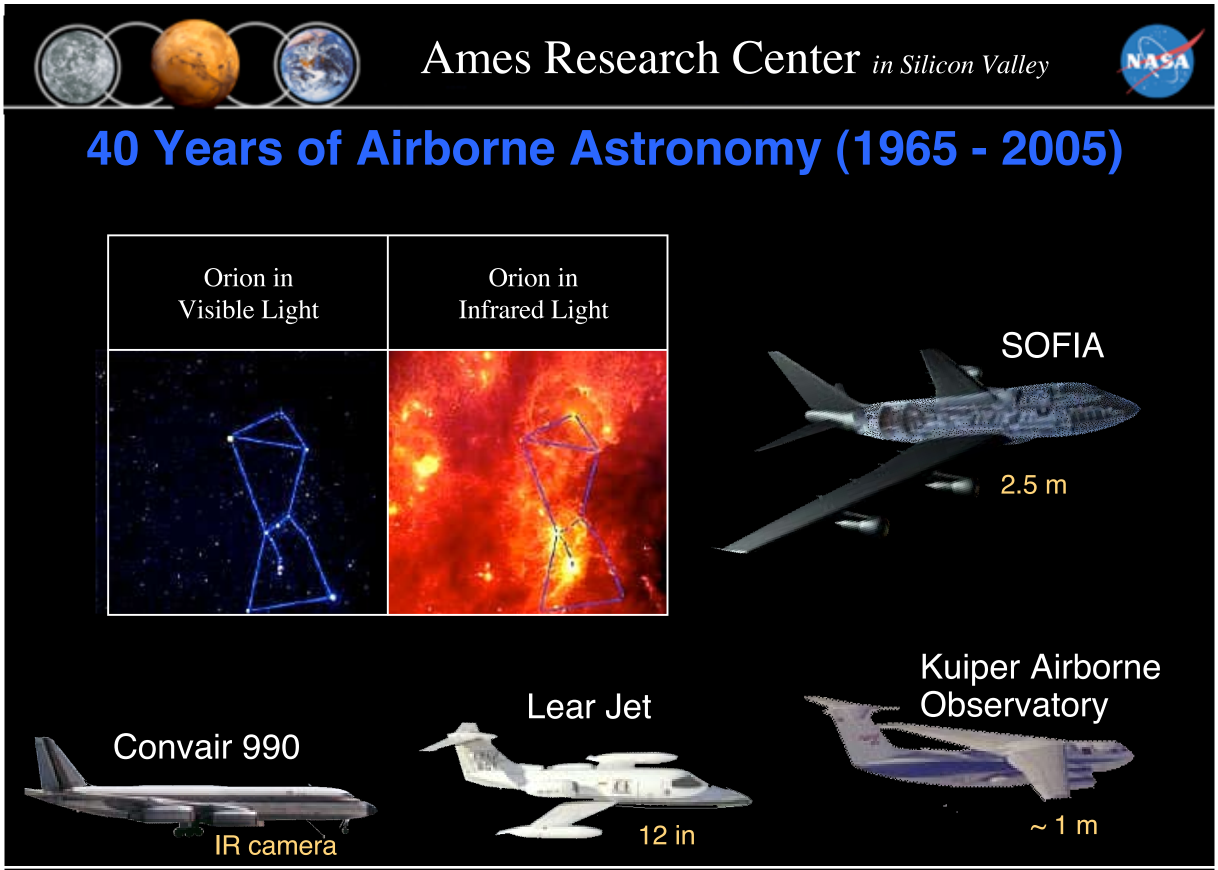

Ames Research Center in Silicon Valley
NASA
Seven Decades of Innovation
Tektites
Apollo
Guidance System
X-36
NASA
Lunar
Science
Institute
2010
Flight Simulator
Blunt Body
Concept
Pioneer
2000
Human Centered
Computing
SOFIA
Apollo Heat
Shield Tests
Galileo
1990
Transonic
Flow
Lifting Body
Viking
1980
Lunar Prospector
Pioneer
Venus
Air
Transportation
System
Kepler
Flight
Research
Life Sciences
Research
1970
Astrobiology
NASA Research Park
Swept-
Back/Wing
1960
Tiltrotor
Apollo
Re-Entry Shape
Kuiper Observatory
ER-2
Nanotechnology
LCROSS
1950
CFD
Conical Camber
1940
6
Ames Overview - 1/2007
Arcjet Research
Hypervelocity Free Flight
80x120 Wind Tunnel
One of the World's Fastest
Operational Supercomputers


Ames Research Center in Silicon Valley
NASA
First Century of Flight, Ames Visitors
Orville Wright
Neil Armstrong


Ames Research Center in Silicon Valley
NASA
NASA Ames Research Center Today
• Science (Earth-Life-Space)
• Astrobiology
• Science Missions
• Exploration Systems
• Small Satellites
• Aviation and Aeronautics
• Innovative Collaborations
• 2300 Employees
• $600+ M Annual Budget
8


Ames Research Center in Silicon Valley
NASA
Astrobiology
• Scientific Study of Life in the Universe
• Three Fundamental Questions
- How does life begin and evolve?
- Does life exist elsewhere in the universe?
- What is life's future on Earth and beyond?
• NASA Astrobiology Institute at Ames
- Dr. Carl Pilcher, Director
- 12 Lead Member Institutions
- 6 International Partners


Ames Research Center in Silicon Valley
NASA
Science Missions
• History of Successful Mission Management
• 40 Years of Airborne Astronomy
• Stratospheric Observatory For Infrared Astronomy (SOFIA)
• Kepler Mission - Search for Habitable Planets
• Lunar Crater Observation and Sensing Satellite (LCROSS)
• Near Earth Objects


Ames Research Center in Silicon Valley
NASA
40 Years of Airborne Astronomy (1965 - 2005)
Orion in Visible Light
Orion in Infrared Light
SOFIA
2.5 m
Kuiper Airborne Observatory
Lear Jet
Convair 990
IR camera
12 in
~ 1 m


Ames Research Center in Silicon Valley
NASA
SOFIA - Stratospheric Observatory for Infrared Astronomy
• Explore the infrared universe flying above interference from the Earth's water vapor atmosphere
• National Academy priority from Decadal Surveys, 1991 & 2001
NASA DLR
SOFIA
2.8 m IR telescope in 747 aircraft
160 flights per year


Ames Research Center in Silicon Valley
NASA
Kepler: The Search for Habitable Planets
• Search for Earth-size and smaller planets in orbit around stars in our galactic neighborhood
• October 2008 Launch


Ames Research Center in Silicon Valley
NASA
Lunar Crater Observation and Sensing Satellite (LCROSS)
• Lunar Kinetic Impactor Mission employed to reveal the presence and nature of water ice on the Moon
• LCROSS piggy backing on Lunar Reconnaissance Orbiter
• October 2008 launch
14
Ames Overview - 1/2007

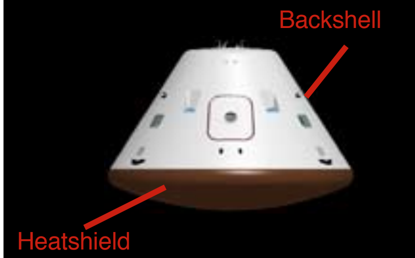

Ames Research Center in Silicon Valley
NASA
Small Satellites
• Advance the effectiveness of low cost experiments in support of NASA's exploration missions and advanced technical demonstrations
- Lasercom/IP
- XNAV
- Lunar Micro-Lander
- Lunar Science Orbiter
- GeneBox
- GeneSat-1


Ames Research Center in Silicon Valley
NASA
Exploration Systems
• Thermal Protection Systems
• Mission Operations
• Integrated Systems Health Management
• Software Deliverables to Missions
• Information Technology (Autonomy, Human Factors)
• Super Computing
16

Ames Research Center *in Silicon Valley*

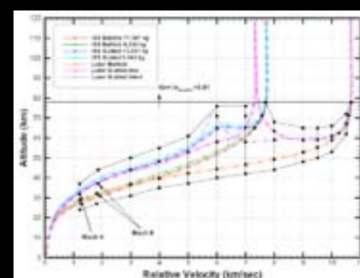
Thermal Protection Materials and Arc-Jet Facility

- **ARC leads development of Orion's thermal protection system**
- **Testing and/or materials for all US planetary atmospheric entry systems; Support for Apollo, Shuttle, and Crew Exploration Vehicle**



Design
Lunar Direct Return & Low Earth Orbit heat shield

Testing
Ablative Thermal Protection



Analysis

Ames Research Center *in Silicon Valley*

Information Technology

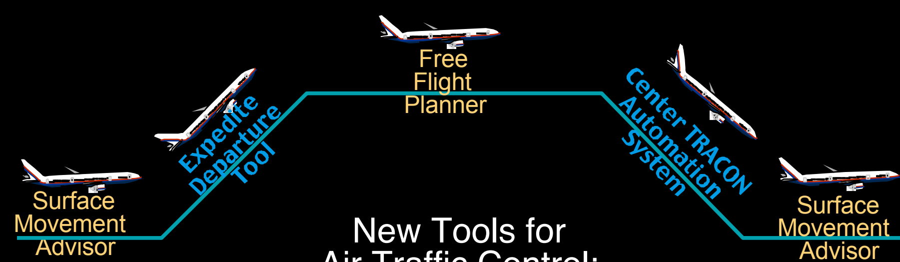
- **Intelligent Adaptive Systems**
  - Autonomous systems and robotics
  - Integrated Systems Health Management
  - Robust software systems
- **Super Computing, Large Data Sets & Datamining**
  - High-end computing resources, integrated with modeling and simulation, data analysis, and visualization technologies
- **ARC provides overall management of Information Technology systems for Constellation**

18 Ames Overview - 1/2007

Ames Research Center *in Silicon Valley*

Air Traffic Management/Air Traffic Control

- **Traffic Management Advisor (TMA) has had significant positive impact on the National Airspace System (NAS)**
- **Estimated annual savings of $400M/year to airlines**

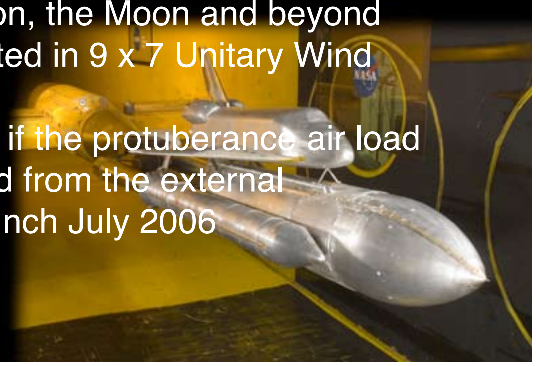


New Tools for
Air Traffic Control:
TMA--Deployed at 11 sites--
Soon to be nation-wide!!

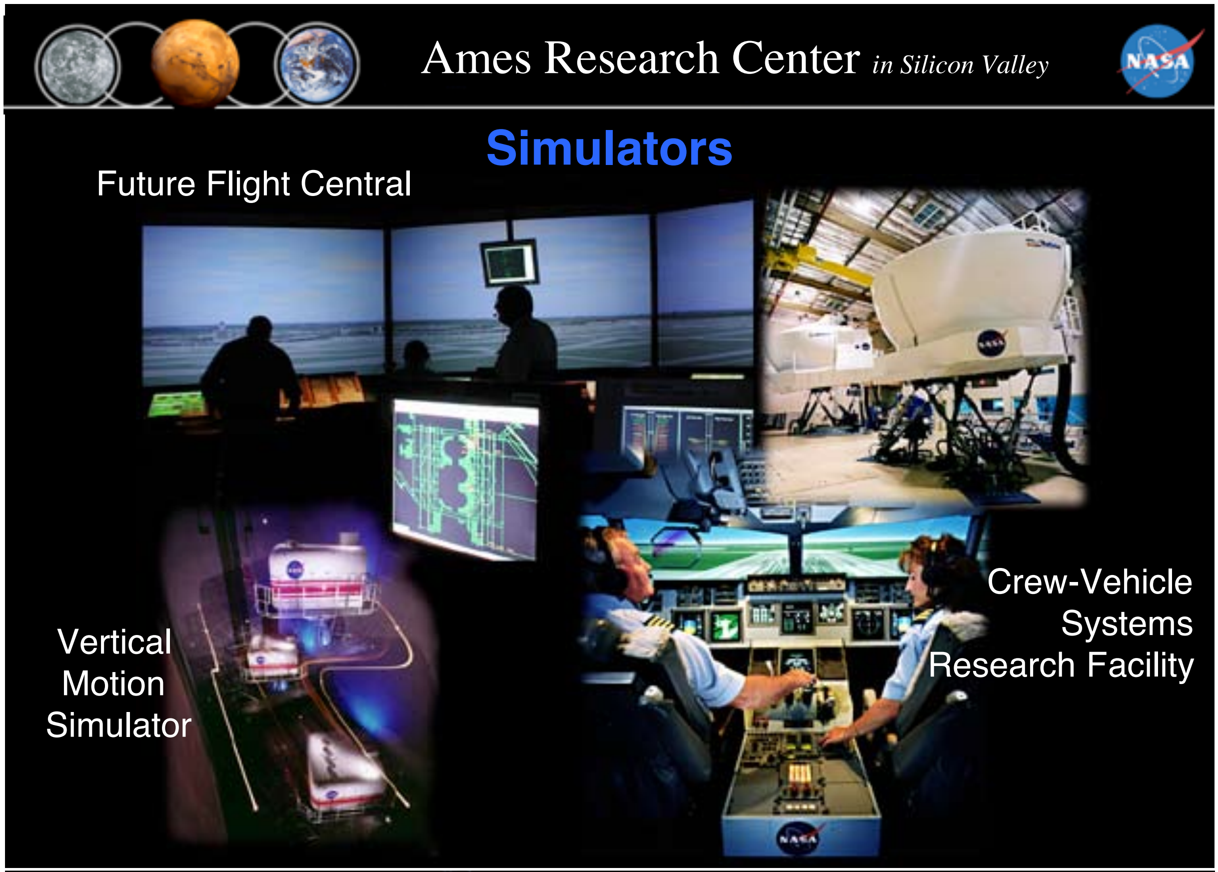
Ames Research Center *in Silicon Valley*

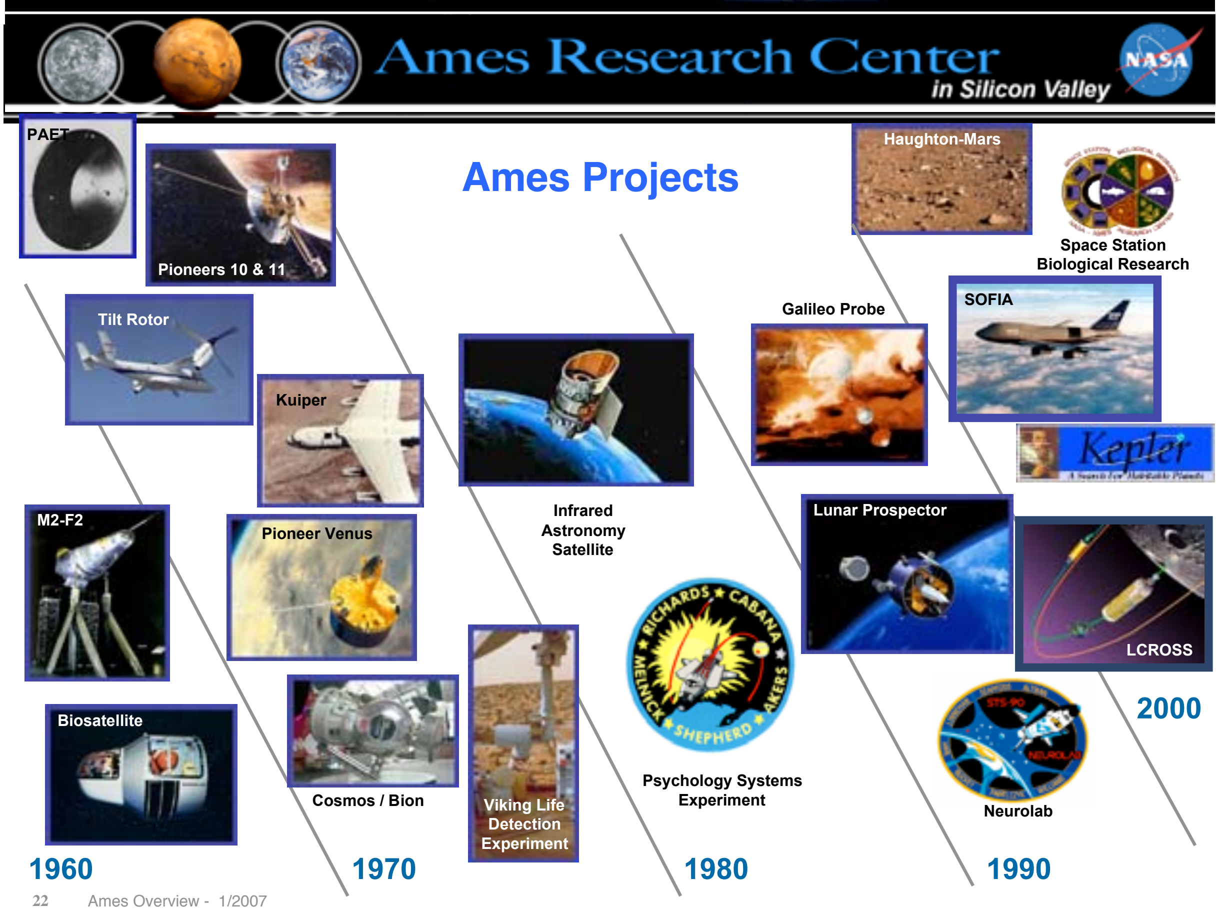
Wind Tunnels

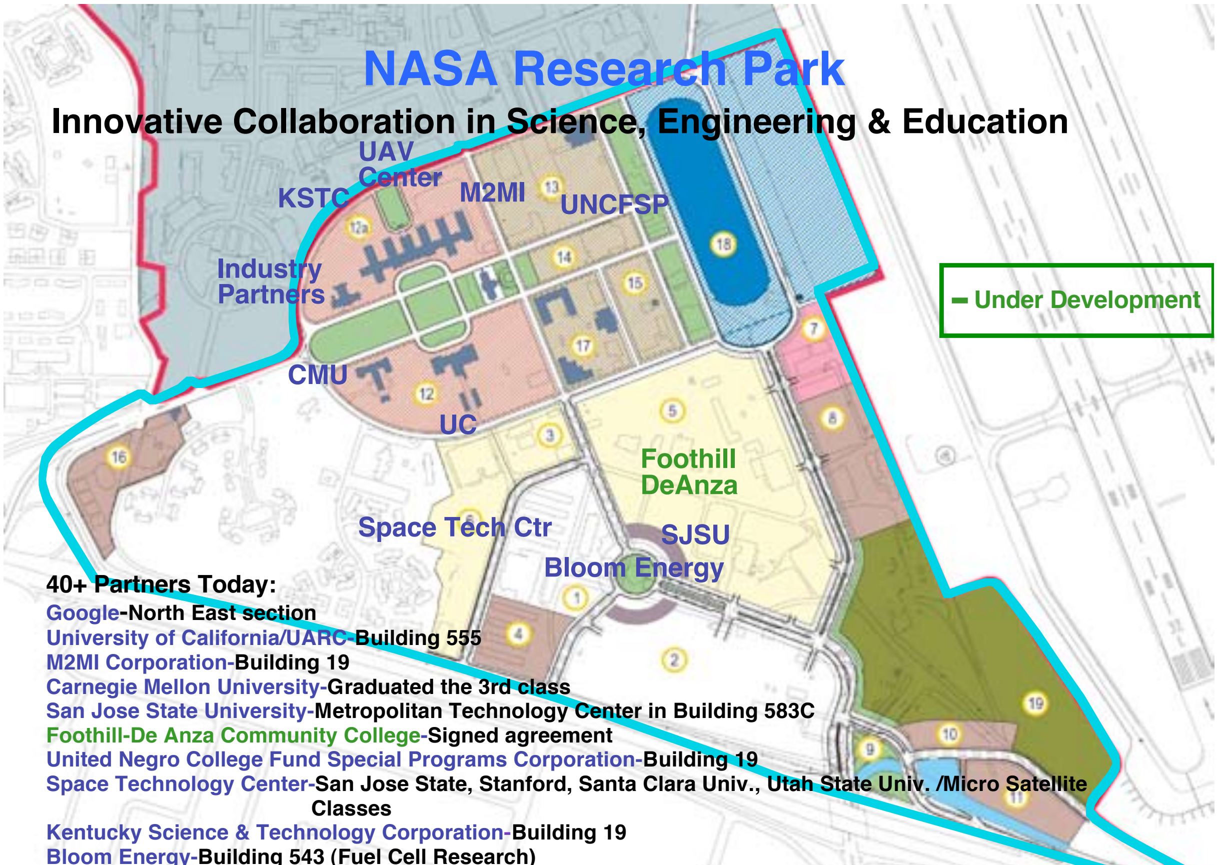
- **Space transportation vehicles require significant wind tunnel testing to address configuration development for planetary exit and reentry challenges**
  - Scale model CEV tested in 11 x 11 Unitary Wind Tunnel Complex (March, 2006)
    - CEV will be NASA's new spaceship that will fly astronauts to the International Space Station, the Moon and beyond
  - Space Shuttle 3% scale model tested in 9 x 7 Unitary Wind Tunnel Complex (March, 2006)
    - Provided data to aid in deciding if the protuberance air load (PAL) ramps should be removed from the external tank for the STS-121 shuttle launch July 2006



20 Ames Overview - 1/2007


Ames Research Center in Silicon Valley
NASA
Simulators
Future Flight Central
Vertical
Motion
Simulator
Crew-Vehicle
Systems
Research Facility

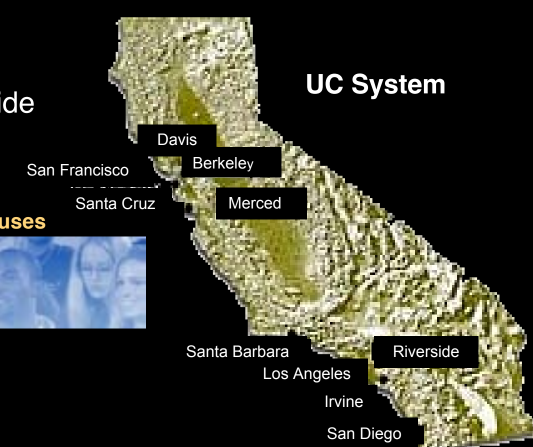

Ames Research Center
in Silicon Valley
NASA
Ames Projects
PAET
Pioneers 10 & 11
Tilt Rotor
Kuiper
M2-F2
Pioneer Venus
Biosatellite
Cosmos / Bion
Viking Life Detection Experiment
Infrared Astronomy Satellite
Psychology Systems Experiment
Galileo Probe
Haughton-Mars
Space Station Biological Research
SOFIA
Kepler
Lunar Prospector
LCROSS
Neurolab
1960
1970
1980
1990
2000
22
Ames Overview - 1/2007



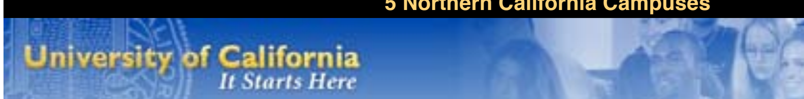
Ames Research Center *in Silicon Valley*

University Affiliated Research Center (UARC)

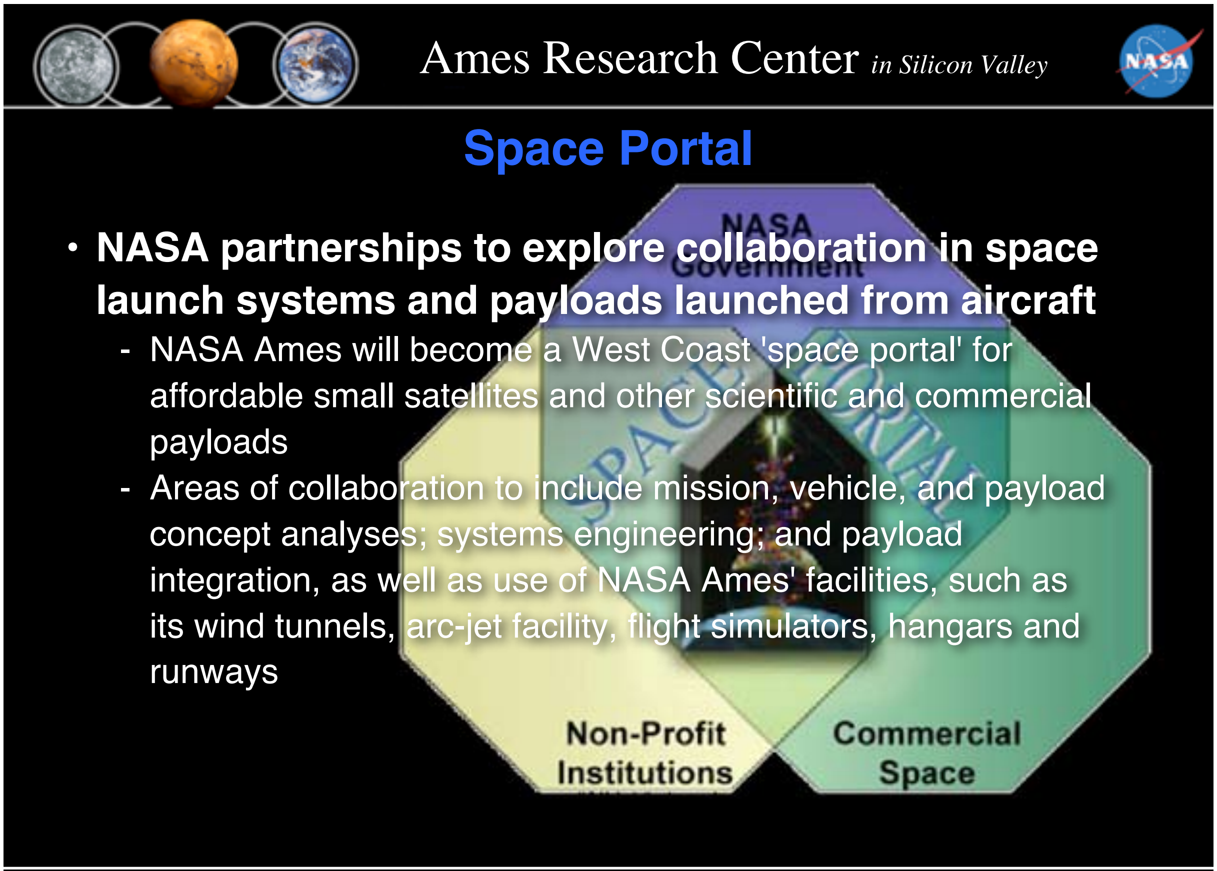
- 10 year, $330 M contract between NASA Ames and University of California
- UC Santa Cruz is lead UC institution-Ranked 1st in Space Science by ISI
- Beyond grants and support contracts
- Tasks that are part of NASA's critical milestones
- Flexibility to change tasks as needs arise
- UC: 10 Campuses, 3 National Laboratories
- $18B annual budget
- 4 UC campuses rated among top 15 worldwide



5 Northern California Campuses



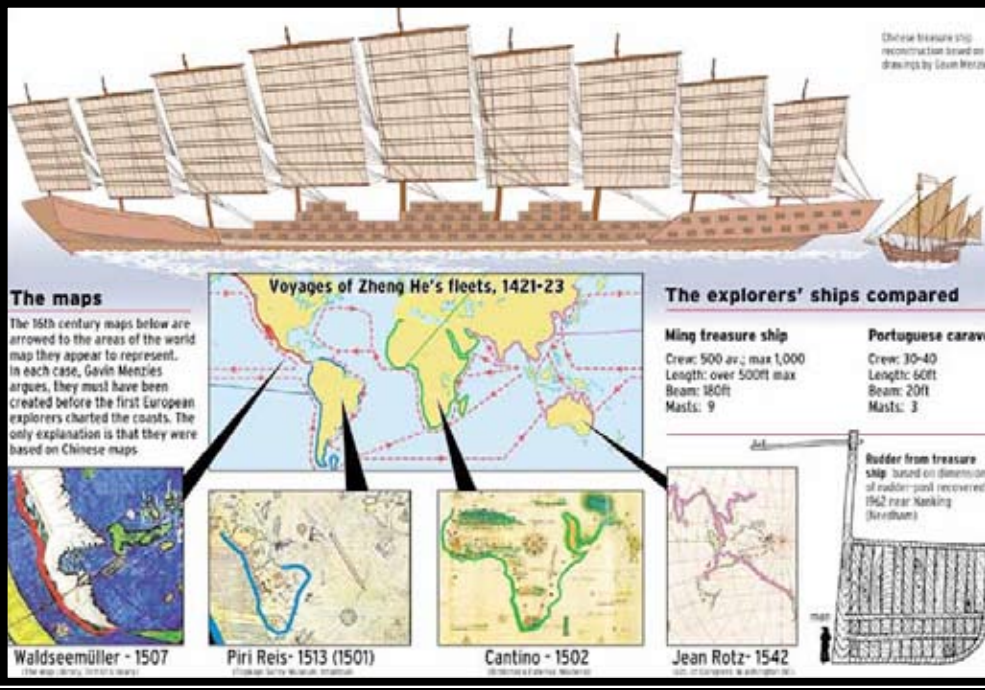
24 Ames Overview - 1/2007


Ames Research Center in Silicon Valley
NASA
Space Portal
• NASA partnerships to explore collaboration in space launch systems and payloads launched from aircraft
- NASA Ames will become a West Coast 'space portal' for affordable small satellites and other scientific and commercial payloads
- Areas of collaboration to include mission, vehicle, and payload concept analyses; systems engineering; and payload integration, as well as use of NASA Ames' facilities, such as its wind tunnels, arc-jet facility, flight simulators, hangars and runways
NASA Government
SPACE PORTAL
Non-Profit Institutions
Commercial Space


Ames Research Center in Silicon Valley
NASA
NASA Ames Educational Activities
Student Space Biology Research Program (Ames PAO Education Program)
Minority University Research and Education Program (MUREP)
Foothill DeAnza Internship Program
Summer High School Apprentice Research Program (SHARP)
JASON Project
INTERNATIONAL SPACE UNIVERSITY
ISU
NASA Explorer Schools
Ames Cooperative Education Programs
Robotics Alliance Project
Ames Exploration Encounter
Stanford Visiting Professors Programs
1950
1960
1970
1980
1990
2000
Santa Clara University
First MOU with Santa Clara University
CAPP
California Academic Partnership Program
Aero Expo
26 Ames Overview - 1/2007

Ames Research Center *in Silicon Valley*

If You Stop Technology…



Ames Research Center *in Silicon Valley*

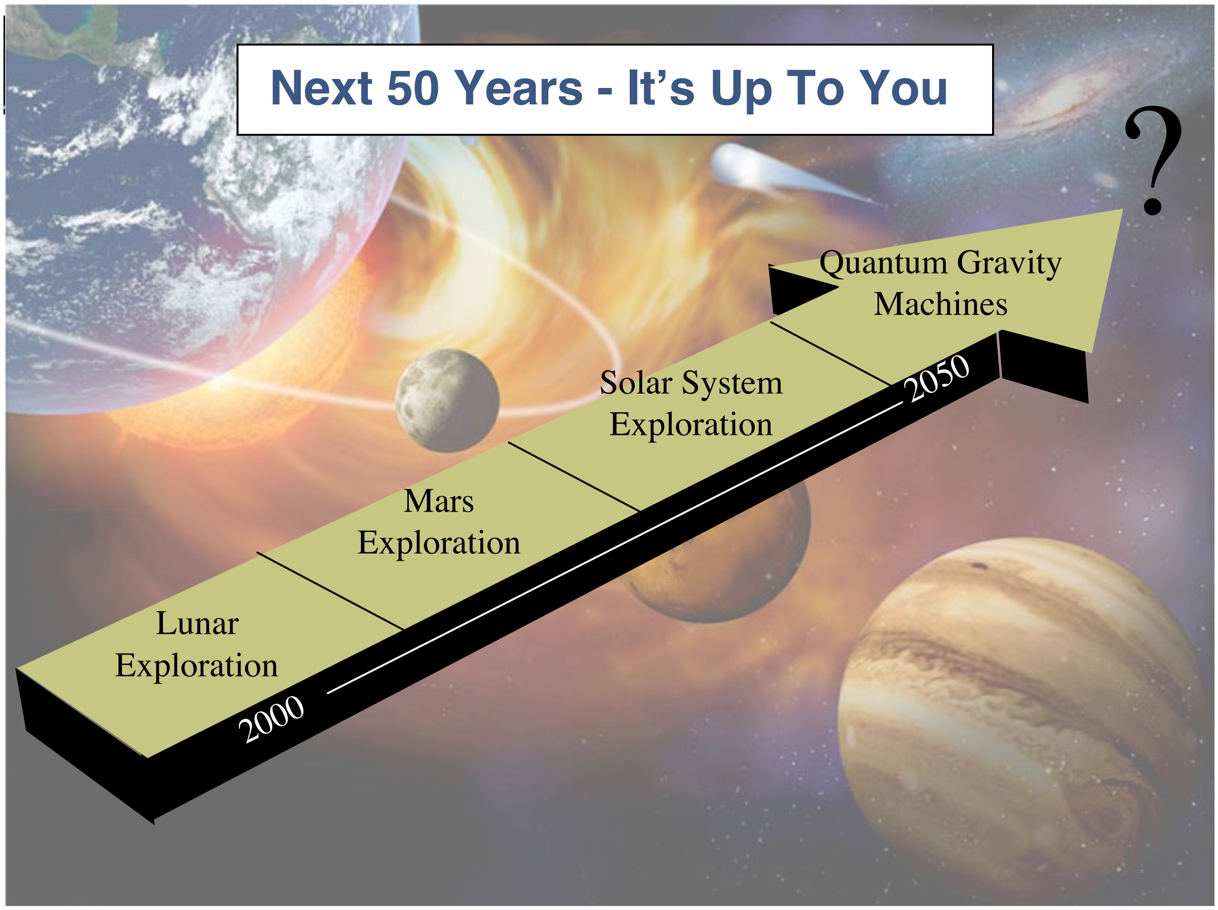
Technology Development is Non-Linear

*** President Hoover Commission in 1929**

- **Predicted (Linear extrapolation)**
  - Airplane development
  - Sound pictures
  - Radio
  - Tractor
- **Missed**
  - Nuclear technology
  - Computer technology
  - Genetic engineering
  - Earth orbiting satellites

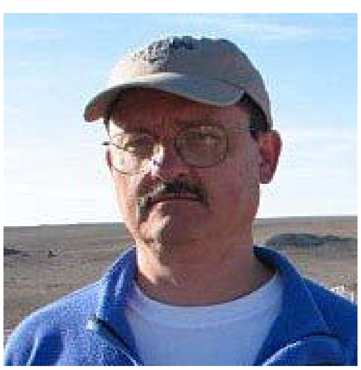
**** "The influence of invention and discovery"***

28 Ames Overview - 1/2007


Next 50 Years - It's Up To You
?
Quantum Gravity
Machines
2050
Solar System
Exploration
Mars
Exploration
Lunar
Exploration
2000

Matthew Reyes *Exploration Solutions, Inc.* and **Keith Cowing** *SpaceRef Interactive, Inc.*

Matthew F. Reyes is the founder and CEO of Exploration Solutions, Inc., a corporation dedicated to improving science education and public outreach through the production of High Definition, interactive multimedia for classrooms and museums, as well as the internet and television. Although born in Hawaii and traveled extensively in North and South America, Matt is a true Floridian, having been raised in Homestead and currently living a short commute from the rockets launched at NASA Kennedy Space Center. Matthew received a B.S. from the University of Florida, majoring in Environmental Horticulture with a specialization in Natural Resource Ethics and Policy, and is currently wrapping up his Masters in Plant Molecular Biology. He has extensive, hands-on experience in fields as diverse as computer science, evolutionary biology, landscape horticulture, motorcycle repair, photography, radio & optical astronomy, and underwater archeology. In 2000, Matthew was selected as a Research Associate for the NASA Astrobiology Academy, and subsequently hired as an Associate Scientist for Lockheed Martin - Missiles & Space at NASA Ames Research Center. In 2003, Matt worked with Robert Ferl's laboratory at UF developing astronaut training procedures and researching plant responses to microgravity aboard the KC-135. In 2005 Matt enlisted with the Zero Gravity Corporation as a volunteer Flight Specialist, and for three years served as ZERO-G Director of Technical Operations. On behalf of the Challenger Learning Center, Matthew spent two weeks at the Haughton-Mars Project Research Station (HMP) starring in webcasts for kids across the United States. Matthew's first project after founding Exploration Solutions was to video document an expedition to the Galápagos Islands by Rollin College, working with the local non-profit Galápagos ICE to improve education and health among the indigenous Galápageño population. Read more about Matt's adventures at his website: www.motorbikematt.com



Keith Cowing is trained as a biologist (M.A. and B.A. degrees) and has a multidisciplinar background with experience and expertise that ranges from space shuttle and space station payload integration and biomedical peer review to freelance writing and website authoring. Keith is editor and webmaster of the somewhat notorious NASA Watch, an online publication devoted to the free and uncensored exchange of information on space policy and NASA operations. This website is read regularly within NASA, Congress, and the global space community. Keith is also editor of SpaceRef.com an online space news and reference resource and OnOrbit.com a new, space-oriented social website Keith donated his time to serve as an organizer and later, a the proceedings co-editor, for the NASA Administrator's Symposium "Risk and Exploration:

Earth, Sea, and the Stars” which was held at the Naval Postgraduate School in September 2004. Next Generation Exploration Conference-2 l 2008 31 DRAFT 6/16/08 Keith was co-chair with Leroy Chiao of a successor to this event, “Risk and Exploration: Eart As A Classroom”, which was held at Louisiana State University in October 2007. Keith has been involved with the Haughton-Mars Project (HMP) since the mid 1990’s. Keith and his SpaceRef business partner Marc Boucher donated an experimental greenhouse which they constructed on Devon Island in the Summer of 2002. Keith returned to Devon Island for another month in 2003. Keith visited Devon Island again in July in 2007 as part of a Mars Institute/ Challenger Center education and outreach activity. Keith is a Fellow (National) of The Explorers Club and was a member of a flag expedition to Devon Island (also in 2007). He is also an advisor to the Students for the Exploration and Settlement of Space (SEDS) and is a member of the Board of Directors of the Challenger Center for Space Science Education.

Next Generation Exploration Conference-2
February 12 - 15, 2008 | Moffett Field, CA

Introductions

Keith Cowing
- Former NASA Biologist
- Editor of NASAWATCH.COM
- SPACE REF INTERACTIVE
- OnOrbit.com

Matthew Reyes
- Former NASA Biologist (almost)
- NASA Ames Astrobiology Academy Alumnus
- Former Zero Gravity Corp. Director now Consultant
- Founder of Exploration Solutions, Inc.

Next Generation Exploration Conference-2
February 12 - 15, 2008 | Moffett Field, CA

What is Exploration?

Wikipedia says:
- "Exploration is the act of searching or traveling for the purpose of discovery

What do you think?

Next Generation Exploration Conference-2
February 12 - 15, 2008 | Moffett Field, CA

Reasons to Explore:

1. To Gain Knowledge

2. To Improve the Environment

3. For Personal Fulfillment

Next Generation Exploration Conference-2
February 12 - 15, 2008 | Moffett Field, CA

Sir Francis Galton: *The Art of Rough Travel: Advice from a 19th Century Explorer*

(recast with a contemporary voice)

"It is no slight advantage to a person to have the opportunity for distinctions which exploration affords. If one plans the exploration among scenes and places likely to interest the stay-at-home public, they will probably achieve a reputation that might well be envied by wiser people who have not had these opportunities.

The scientific advantages for exploration are enormous to a person prepared to learn by them. The explorer sees nature working by itself without the interference of humanity, and sees nature from new points of view. Exploration offers undisturbed leisure to answer the questions which perpetually attract the explorer's attention. The consequence is that though scientific travelers are comparatively few, yet out of their ranks a large proportion of the leaders in all branches of science have been supplied.

Next Generation Exploration Conference-2
February 12 - 15, 2008 | Moffett Field, CA

How to Explore:

1. **The Classical Way: Research**
2. Collaborate
3. Start a business
4. Learn New Skills
5. *TEACH!!*

Earth as a Classroom

WEBCAST

Base Camps on Earth, Moon, and Mars

Next Generation Exploration Conference-2

February 12 - 15, 2008 | Moffett Field, CA

Risk & Exploration:

1. Risks need to be accepted, respected, but not feared

2. Bad things happen, we must always move on.

Next Generation Exploration Conference-2
February 12 - 15, 2008 | Moffett Field, CA

Things to think about:

1. Reconsider what Exploration means to you

2. Don't wait for things to come *just-within-reach*, do the easy stuff too.

Ken Davidian *NASA Headquarters*

Ken Davidian currently works for the Exploration Systems Mission Directorate (ESMD) at NASA Headquarters in Washington, D.C., leading the ESMD Commercial Development Policy efforts.

Starting in 1983, Mr. Davidian spent the first years of his career at the NASA Lewis Research Center in Cleveland, Ohio, working for the Space Propulsion Technology Division in the area of analytical and experimental research on the performance of liquid rocket engines.

Between 1997 and 1999, Mr. Davidian was assigned by NASA to work as the Assistant Director of Operations for the Summer Session Program at the International Space University in Strasbourg, France. Upon his return to the center (which had been since renamed to the NASA Glenn Research Center), Mr. Davidian worked in the Plans and Programs Office.

In 2001, Mr. Davidian left government service and entered the private sector in many positions. He has worked for Paragon Space Development Corp. as a consultant in the role of Director of Operations for Cargo Lifter Development GmbH near Berlin, Germany, as Director of Operations for the X PRIZE Foundation in St. Louis, Missouri, and then again for Paragon, as corporate Program Manager in Tucson, Arizona.

In 2004, a move to Washington, D.C. provided Mr. Davidian the opportunity to work on Centennial Challenges, NASA's prize program. He started as a contractor, working for WBB/DMG, and then reentered civil service when he was hired by NASA Headquarters in 2006, becoming both the Program Manager for Centennial Challenges and the ESMD Commercial Development Policy leader.

Mr. Davidian received his B.S. degree in Aeronautical and Astronautical Engineering from the Ohio State University in 1983, and an M.S. degree in Mechanical Engineering from Case Western Reserve University in 1987. He attended the International Space University as a Summer Session Program participant in 1989.

National Aeronautics and Space Administration

2nd Next Generation Exploration Conference

"Entrepreneurial Opportunities in Lunar Development"

Ken Davidian
Commercial Development Policy Lead
Exploration System Mission Directorate
February 12, 2008

Directorate Integration Office

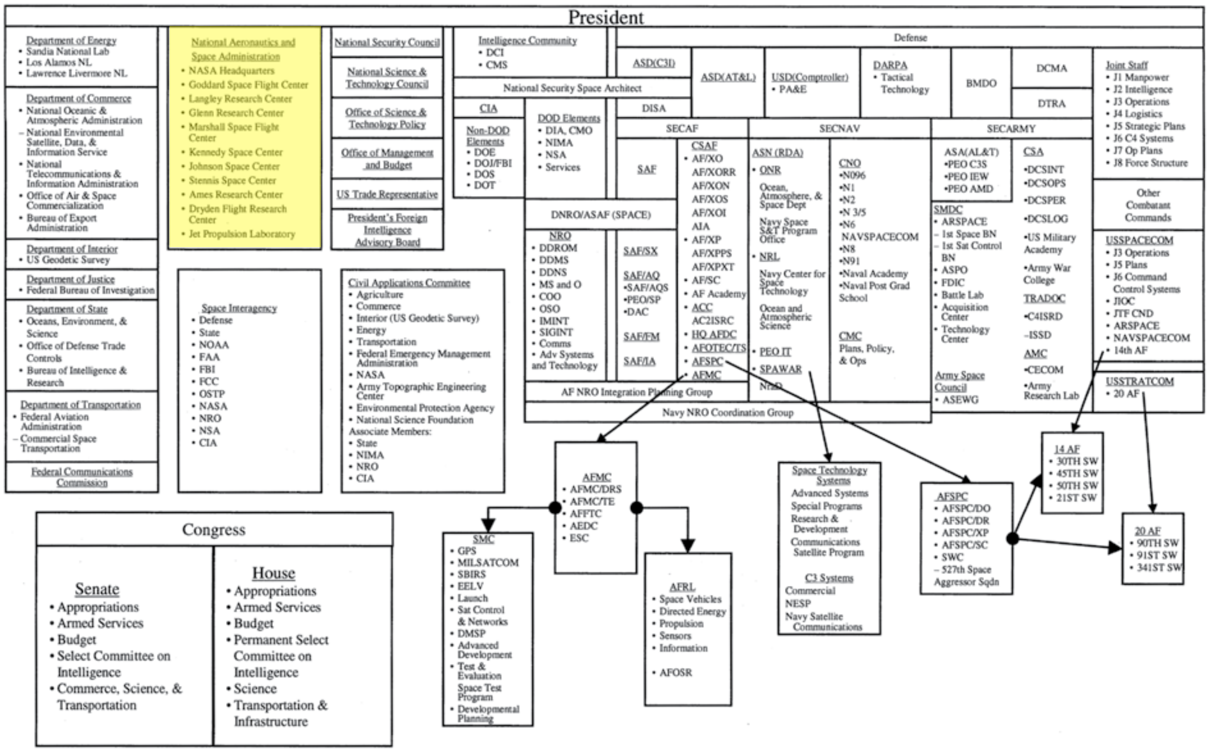
Welcome to NGEC2!

- What is NASA?
- What is Constellation?
- What is the Lunar Architecture?
- What Commerce Work Has Been Done Before?
- What Approaches Has NASA Taken Before?
- What Is the Current Policy?
- What Will We Be Doing This Week?

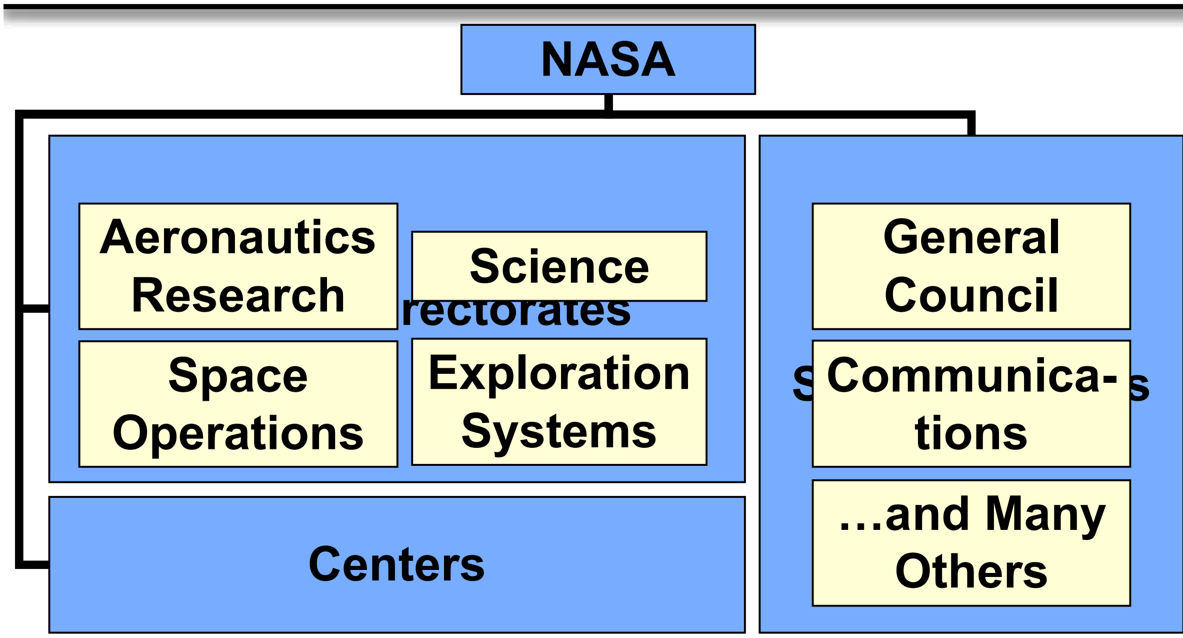
Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 2

What is NASA? The BIG Picture



What is NASA? Focus on NASA



www.nasa.gov/pdf/206349main_Org_Chart_11-07.pdf

One Down, Six To Go!

- What is NASA?
- What is Constellation?
- What is the Lunar Architecture?
- What Commerce Work Has Been Done Before?
- What Approaches Has NASA Taken Before?
- What Is the Current Policy?
- What Will We Be Doing This Week?

Ken Davidian *NASA Headquarters*

NGEC2… the Adventure Continues!

- What is NASA?
- What is Constellation?
- What is the Lunar Architecture?
- What Commerce Work Has Been Done Before?
- What Approaches Has NASA Taken Before?
- What Is the Current Policy?
- What Will We Be Doing This Week?

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 2

2006 GES Data Solicitation Events

DATE	LOCATION	EVENT
24-26 April	Washington, DC	International GES Workshop
11 April – 12 May	Not Applicable	Request For Information
17-19 July	Las Vegas, NV	Lunar Commerce Roundtable
21 July	Las Vegas, NV	Space Frontier Foundation NewSpace Conference
29-30 August	Washington, DC	NASA Lunar Exploration Architecture Plan Workshop

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 4

800 Responses - 23 Subject Categories

- Astronomy & Astrophysics
- Earth Observation
- Geology
- Materials Science
- Human Health
- Environmental Characterization
- Operational Support
- Life Support & Habitat
- Environmental Hazard Mitigation
- Power
- Communication
- Guidance, Navigation & Control
- Surface Mobility
- Transportation
- Operational Environmental Monitoring
- General Infrastructure
- Operations Test & Verification
- Lunar Resource Utilization
- Historic Preservation
- **Development of Lunar Commerce**
- Global Partnership
- Public Engagement
- Program Execution

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 5

Why Go Back To The Moon?

- 130 Business Ideas in 18 Industry Sectors

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 6

Development of Lunar Commerce

- **133 Objectives in This Subject Category**
- **Divided Into Two Objective Categories (Groups)**

Issues:	**Opportunities:**
~~61 Objectives~~	~~72 Objectives~~
9 Subcategories	18 Industry Sectors Represented

- **US Dept of Commerce Export Industry Sectors Used**
  - Int'l Standard Industrial Classification of All Economic Activities (UN)
  - North American Industry Classification System (NAICS)
  - United Kingdom Standard Industrial Classification (UKSIC)
  - Global Industry Classification Standard (GICS, by Morgan Stanley Capital)

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 7

Lunar Commerce Issues

ISSUES	GROUPINGS
• Planning Exploration Process Participation • Planning Exploration to Promote Commerce • Challenging the Status Quo	Contribution to Exploration
• Establishment of New Relationships • Enable Commercial Markets • Provide Government Assistance	Government Participation
• Legal Issues • ITAR and Other Regulatory Issues • Procurement and Financial Issues	Legal, Regulations, Procurement

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 8

Lunar Commerce Issues 1-3

- **Planning Exploration Process Participation**
  – Engage the commercial sector throughout lunar strategy planning to promote new thinking in all aspects of current and future lunar activities.
- **Planning Exploration to Promote Commerce**
  – Engage the commercial sector throughout lunar strategy planning to promote ideas of lunar commerce in all aspects of current and future lunar activities.
- **Challenging the Status Quo**
  – Engage the involvement of the commercial sector throughout the lunar strategy development to question the standard operating procedures and traditional methodologies used by the national space agencies.

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 9

Lunar Commerce Issues 4-6

- **Establishment of New Relationships**
  - Methods of collaboration between and among industry, government, and academia should be actively explored, leading to development of true partnerships in which all parties play a significant role.
- **Enable Commercial Markets**
  - Enable commercial markets for lunar commerce by identifying new market demand and price points. Collaboration between the commercial sector and government could lead to real development of new commercial markets.
- **Provide Government Assistance**
  - New and innovative methods of providing non-monetary government assets of value to the commercial sector should be actively explored to help facilitate the development of lunar commerce.

Presentation to the Department of Commerce Office of Space Commercialization   Directorate Integration Office   10

Lunar Commerce Issues 7-9

- **Legal Issues**
  - Laws that have a negative impact on the development of lunar commercial activities must be reviewed and modified as appropriate to minimize their detrimental effect on industry as a whole.
- **ITAR and Other Regulatory Issues**
  - Regulations and policies that have a negative impact on the development of lunar commercial activities must be reviewed and modified as appropriate to minimize their detrimental effect on industry as a whole.
- **Procurement and Financial Issues**
  - Governments need the ability to use modifications of existing acquisition practices, use new and innovative acquisition practices, or extend the application of make advance purchase, long-term commitment purchases (beyond the current application to utilities and subscriptions) for future goods and services from industry.

Presentation to the Department of Commerce Office of Space Commercialization   Directorate Integration Office   11

Lunar Commerce Opportunities

- **Automotive/Aviation/Marine**
  - Orbit-to-Orbit Services
- **Business Services**
  - Advertising
  - Other Services
  - Trade Promotion
  - Transportation Services and Logistics
  - Travel and Tourism
- **Electrical/Electronics**
  - Electrical Power Generation, Distribution Equipment
  - Broadcasting
- **Environmental**
  - Pollution Control Equipment
- **Hotel & Restaurant**
  - H&R Equipment
- **Industrial Equipment, Services**
  - Chemical Production Machinery
  - Mining and Extraction Equipment
- **Information Technology, Telecommunications**
  - Computer Services
  - Computer Software
  - Telecomm Equipment
- **Materials**
  - Production Machinery
- **Medical/Scientific Products & Equipment**
  - Laboratory and Scientific Products and Equipment
  - Medical Instruments

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 12

Lunar Commerce Opportunity Gaps

- Agriculture (3)
- Automotive, Aviation, Marine (7)
- Building, Construction, Hardware (4)
- Business Services (6)
- Consumer Goods (10)
- Electrical, Electronics (4)
- Environmental (3)
- Franchising Health & Beauty, Fashion (5)
- Hotel & Restaurant Equipment, Food, Food Processing (3)
- Industrial Equipment, Services & Supplies (17)
- Information Technology, Telecommunications (1)
- Materials (2)
- Medical/Scientific Products & Equip (3)
- Safety & Security (1)
- Sports & Recreation (3)

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 13

Prior "Non-NASA" Work

- Moon Miner's Manifesto Classics
- Artemis Project
- Ken Murphy's Lunar Library
- More…

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 14

Coming Up Next…

- What is NASA?
- What is Constellation?
- What is the Lunar Architecture?
- What Commerce Work Has Been Done Before?
- **What Approaches Has NASA Taken Before?**
- **What Is the Current Policy?**
- **What Will We Be Doing This Week?**

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 15

National Aeronautics and Space Administration

2nd Next Generation Exploration Conference

"Entrepreneurial Opportunities in Lunar Development"

Ken Davidian
Commercial Development Policy Lead
Exploration System Mission Directorate
February 12, 2008

Directorate Integration Office

NGEC2: "Rubber, Meet Road."

- What is NASA?
- What is Constellation?
- What is the Lunar Architecture?
- What Commerce Work Has Been Done Before?
- What Approaches Has NASA Taken Before?
- What Is the Current Policy?
- **What Will We Be Doing This Week?**

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 2

Agenda

- Goal
- Scope
- Assumptions
- Definitions
- Work Tasks

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 3

NGEC2 Goal

- To identify and analyze entrepreneurial opportunities for commercial space capabilities that expand the Earth's economic sphere of influence out to, and including, the Moon.

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 4

NGEC2 Scope

- Scope of **ECDP**
  - NASA Exploration Architecture Parts
  - Non-NASA Exploration Architecture Parts
  - Other Capabilities That Support NASA
- Scope of **NGEC2**
  - Brainstorming Sessions: Anything Goes
  - Encompass all industry sectors.
  - Market Analysis: Focus on Near-Term Ideas

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 5

Assumptions

- Baseline assumptions would be minimal.
  - If it exists today, it exists.
  - If it doesn't exist today, I wouldn't assume it exists.
- Include realistic possibility of things existing in the future.

Presentation to the Department of Commerce Office of Space Commercialization

Directorate Integration Office 6

Def'n 1: Lunar Commerce Development

- "Commercial Lunar Capabilities"
  - The private sector production, manufacture, support, or operation of any good, service, facility, vehicle, or piece of equipment,
  - for lunar operations or for the testing of lunar-related technologies,
  - purchased by another private sector company or by the government through means other than traditional cost-plus government contracting.

Def'n 2: Entrepreneurial

- Characteristics of NewSpace Companies
  - High financial risk level: private, personal
  - High technological achievement level
  - High reliance on non-government customers
  - High Sensitivity to Launch Costs
    - Moving atoms, not electrons

Working Group Tasks

1. Reviewing past work to identify potential industry sector commercial activities.
2. Brainstorming to identify new potential industry sector commercial activities.
3. Creating a glossary of potential industry sector commercial activities.
4. Performing a "Time-Phasing Analysis".
5. Performing a "Market Analysis"
6. Creating a Commercial Entity Database

Table 1. Possible Commercial Space Industries

GES = Ideas Generated During GES Activities

Time Frame time, t	Near-Term t < 10 yrs	Mid-Term 10 < t < 20 yrs	Far-Term 20 < t < 30 yrs
Uncrewed Vehicles	• Suborbital • Earth Surface ↔ LEO • LEO ↔ LLO ↔ Moon Surface	• Cis-Lunar ↔ LMO ↔ Mars Surface	
Crewed Vehicles	• Suborbital[GES] • Earth Surface ↔ LEO[GES]	• LEO ↔ LLO[GES] ↔ Moon Surface[GES] • Cis-Lunar ↔ LMO ↔ Mars Surface	
Vehicle Subsystems	• Propulsion Systems (Engines, Tanks, etc.) • Docking Systems • Communications • EVA Suits • Pressure Suits		
Earth Orbital Services[GES]	• Infocomm (Existing) • Habitat • Fuel Depots	• Power[GES]	• Maintenance • Power[GES]
Lunar Orbital, Surface Services	• Infocomm (Broadcasting, Advertising, etc.)[GES]	• Surface Habitat[GES] • Surface Power • Telerobotic Services • ISRU Excavation, Extraction[GES] • Medical Labs[GES]	• Too many to list
Mars Orbital, Surface Services		• Infocomm[GES]	• Surface Habitat • Surface Power • Telerobotic Services • ISRU Excavation, Extraction

Table 2. Market Analysis Results

Near-Term Commercial Possibility	USG Supply	USG Demand	Private (incl. non-US) Supply	Private (incl. non-US) Demand	ECDS Activity
Uncrewed, Crewed Transportation: Earth Surface ↔ Suborbital	• None	• NASA (SMD, ESMD)* • DoD*	• Scaled Composites* • LLC Teams (10x, including Armadillo*, Masten*, U-Rocket*, etc.) • Others (RpK*, SpaceDev*, Canadian Arrow*, XCOR*)	• Virgin Galactic (VG) • Space Tourism	• Prizes (Lunar Lander Challenge)
Uncrewed Transportation : Earth Surface ↔ LEO	• Prime Contractors-ULA (Atlas, Delta) • NASA (Ares V)*	• NASA (SOMD, SMD) • USG IC • DoD	• Non-US (Russia, Arianespace) • Funded SAA (SpaceX*, RpK*) • Unfunded SAA (SpaceDev*, t/Space*, SpaceHab*, CSI*, PlanetSpace*)	• Infocomm • Bigelow*	• COTS (in progress)
Uncrewed Transportation: LEO ↔ LLO ↔ Moon Surface	• NASA LSAM-Cargo*	• NASA (SOMD, SMD)*	• None	• None	• None
Crewed Transportation: Earth Surface ↔ LEO	• NASA (Ares I)*	• NASA (SOMD)*	• Non-US (Russia, China*) • Funded SAA (SpaceX*, RpK*) • Unfunded SAA (SpaceDev*, t/Space*, SpaceHab*, CSI*, PlanetSpace*)	• Space Tourism • Bigelow*	• COTS (in progress)
Vehicle Subsystems: Propulsion Systems	• Prime Contractors (Boeing-RPW, ATK, Aerojet, L-M)	• NASA (Ares I, Ares V, LSAM) • DoD (ORS, etc.)	• Vehicle Developers (SpaceX*, PlanetSpace*, SpaceDev*, Masten*, U-Rocket*, AirLaunch*, etc.) • Propulsion System Developers (XCOR*, Orion*, etc.)	• Vehicle Developers (RpK*, etc.)	• None
Vehicle Subsystems: Docking Hardware	• NASA (ESMD-LIDS)*	• NASA SOMD (Ares I, Ares V, ISS)	• SpaceX* • Swales*	• Vehicle Developers (SpaceX*, PlanetSpace*, SpaceDev*, RpK*, etc.)	• None
Vehicle Subsystems: Communications	• NASA (SOMD-TDRSS) • DoD	• NASA (SOMD-ISS) • DoD	• SpaceX* • Cisco*	• Vehicle Developers (SpaceX*, PlanetSpace*, SpaceDev*, RpK*, etc.)	• None
Vehicle Subsystems: EVA Suits	• Prime Contractors (Hamilton-Sundstrand)	• NASA (SOMD)	• Oceaneering, PSDC	• Bigelow	• None
Vehicle Subsystems: Pressure Suits	• Prime Contractors (David Clark)	• NASA (SOMD)	• PSDC, de Leon* • Orbital Outfitters*	• Space Tourism (VG)* • Bigelow	• None
On-Orbit Services: Habitat	• NASA (ISS)*	• NASA (SOMD, SMD, ESMD)*	• Bigelow (Genesis modules currently)*	• Manufacturing (S-HAB)* • Non-US Gov't A'nauts*	• None
On-Orbit Services: Fuel Depots	• None	• None	• None	• None	• None
Lunar Orbit/Surface Services: Infocomm	• None	• NASA (ESMD)*	• None	• ILO (SpaceDev, Durst)	• None

** Emerging*

Ready? Set?...

- What is NASA?
- What is Constellation?
- What is the Lunar Architecture?
- What Commerce Work Has Been Done Before?
- What Approaches Has NASA Taken Before?
- What Is the Current Policy?
- What Will We Be Doing This Week?

Presentation to the Department of Commerce Office of Space Commercialization | Directorate Integration Office 12

Nicholas Skytland & Garret Fitzpatrick *NASA, JSC*

Nicholas Skytland is Project Manager of the EVA Physiology, Systems and Performance Project (EPSP) within the Human Adaptation and Countermeasures Division of the Space Life Sciences Directorate. In this role he is responsible for integrating inputs from life science disciplines within the Human Research Program into an operationally driven research program. Additionally, Nicholas is leading an effort to provide a framework for strategic public interactions with the goal of offering individuals, academia, companies, and space agencies around the world a common access point to directly contribute to space exploration and Space Life Sciences. Nicholas is one of the original co-authors on Generation Y Perspectives presentation. Nicholas is currently on rotation in support of NASA's deputy associate administrator for strategic partnerships.

Prior to his position in Space Life Sciences, Nicholas worked in the Mission Operations Directorate at the Neutral Buoyancy where he served as the facility interface for training operations and coordinated astronaut extra-vehicular activity (EVA) training and provided real-time flight support for International Space Station (ISS) and Space Shuttle programs. In 2004, Nicholas worked for the X PRIZE Foundation and was instrumental in the planning and support of the first privately funded, manned space launch event of SpaceShipOne in the Mojave Desert. Nicholas holds a master's degree from the International Space University in Space Studies and a bachelor's degree from Valparaiso University in Mechanical Engineering.

Garret Fitzpatrick graduated from the University of Wisconsin-Madison with a B.S. in Engineering Mechanics and Astronautics and a certificate in International Engineering. He is now a Shuttle Crew Escape Engineer at NASA Johnson Space Center, primarily as the lead cooling system engineer for Shuttle astronaut cooling and the hardware manager for the International Space Station Portable Breathing Apparatus. He is also a writer and is involved in various strategic communications work at JSC.

Generation Y Perspectives

Meet Garret, Kristen, Aaron and Nick

Our

friends

think that

we are

rocket

scientists

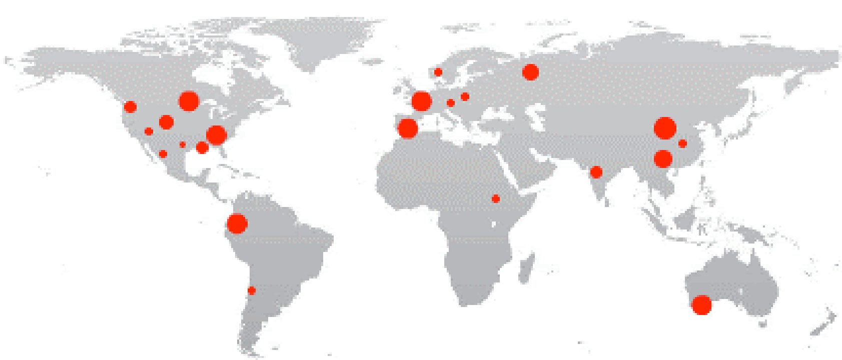
and

astronauts

Because we work here

But truthfully, we tend to work just as much here.

Last week, we interacted with people from here …



… friends, family, classmates, colleagues, even strangers.

They all wanted to know more
about what we do at NASA.™

So we got to thinking…

Why aren't they connected to NASA?

Why isn't a whole generation
connecting to NASA?

We are part of Generation Y.

This presentation is our
perspective.

(But keep in mind that our generation will be asked to pay the majority of the tax bill for the vision for space exploration)

That's $124B through the first lunar landing (FY06–FY18).

NASA has a brand and a message.

We don't want to talk about that.

We want to talk about why our generation isn't connecting to it.

Because we aren't connecting to it…

…young people, both inside and outside of NASA.

And we think they SHOULD connect to it.

Because what NASA does is important.

…to everyone.

The world is connected today in ways that are shattering traditional communications concepts.

And NASA is in a position to *lead the world* in exploring new frontiers.

Engaging people in this exploration is not just an opportunity.

It is a responsibility.

01 Connected Generation

The traditional concept of
top-down, one-way
communications strategy
is ***dead***.

(It is **NOT** dying. It is *dead*.)

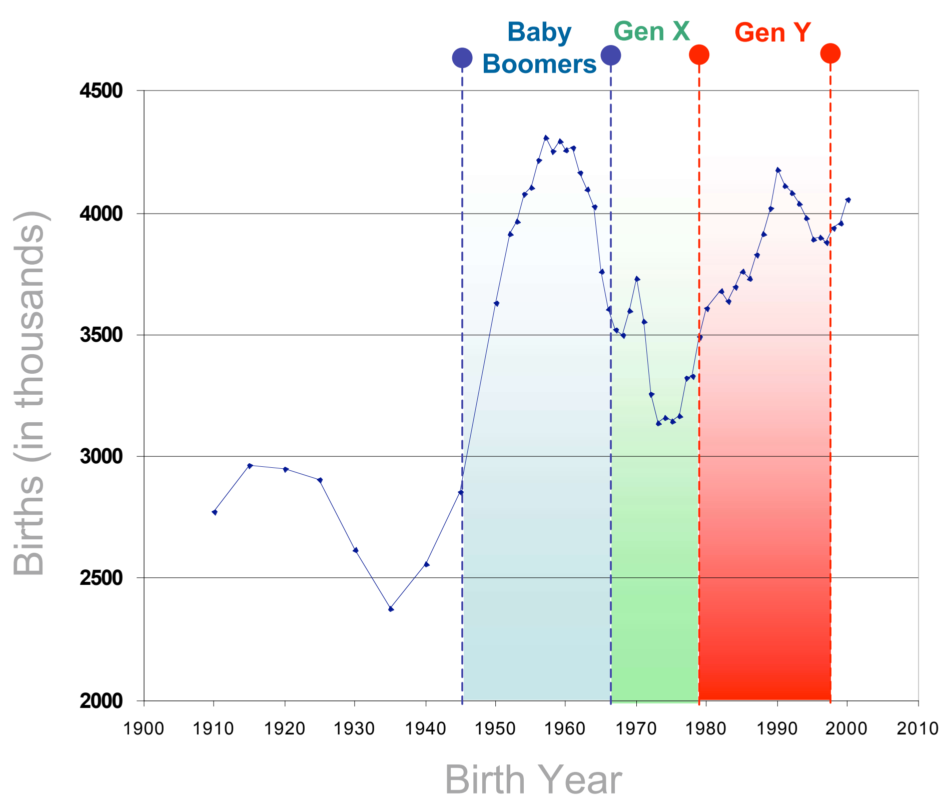
Generation Y is a completely new generation.

Roughly speaking,
Generation Y is defined as -

1977	< Birth Date >	2000
31	< Current Age >	8

There are over 70 million people in the U.S. belonging to our generation

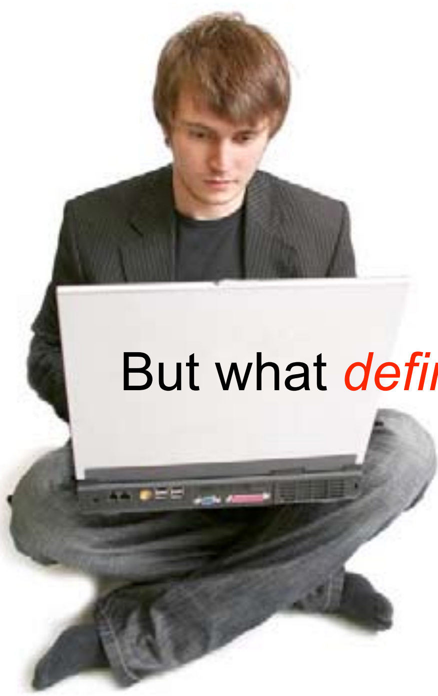
And just like the Baby Boomers, *we* are a large group of people that is IMPACTING society



Generation Y is currently 25% of the workforce

and is projected to be 47% of the workforce by 2014.

Is NASA ready?



But what *defines* Generation Y?

Likes mentors

Global

Instant information

Demands instant gratification

empowered

Wired

Expecting (NOW! Not 5 minutes from now)

Attracted to Large Social Movements

multi-tasking

Quickly bored

Mobile

Interdependent

Impatient if delayed… but highly adaptable.

And there are a lot of things that made us the way we are.

We were the first generation to grow up with ***cable*** *in our homes*

…Studies say this leads to ***shorter attention spans***

…And chronic ***boredom****.*

We are used to ***DIVERSITY***

…after all, we grew up in diverse environments.

We grew up with

TALK SHOWS

And REALITY TV.

For our generation, TV is not passive entertainment

it is an *interactive experience!*

And our lives and outlooks have been shaped by this.

"Anyone can be a star …"

"Everyone deserves to have their say."

"Getting heard and having a say are not only easy, they seem natural."

Wait! You just described my generation.

Maybe there are some similarities. But there are very important differences.

Such as different formative experiences.

Baby Boomers were shaped by:

Vietnam

The "Big Three" TV networks

The Cold War

The Kennedy and King Assassinations

Handicapped Rights

Civil Rights

The Feminist Movement

The Right to Privacy

Rock Music

Gay Rights

And,

Generation Y has been shaped by:

Columbia Accident

The 2000 Election Crisis

Internet

Columbine

The Iraq War

9-11

Reality TV

Terrorism

Cell Phones

Starbucks

Cable

Gaming

And those life experiences made us:

Lack trust in corporations and government
Focus on personal success
Have a short-term career perspective
Gets easily bored
Extremely independent
See no clear boundary between work and life
Empowered and optimistic
Sacrifice economic rewards for work-life balance
Expect to work anytime, anyplace
Connect with people in new and distinctive ways
Comfortable with globalization
Racially and culturally diverse

02 Perspectives

As a whole, people of Generation Y are not interested in space exploration.

This is a FACT.

A majority of Gen Y between 18 and 24
Are not aware or not engaged in NASA's mission

Support is higher among Asian-Americans.

40%

Forty percent oppose NASA's mission

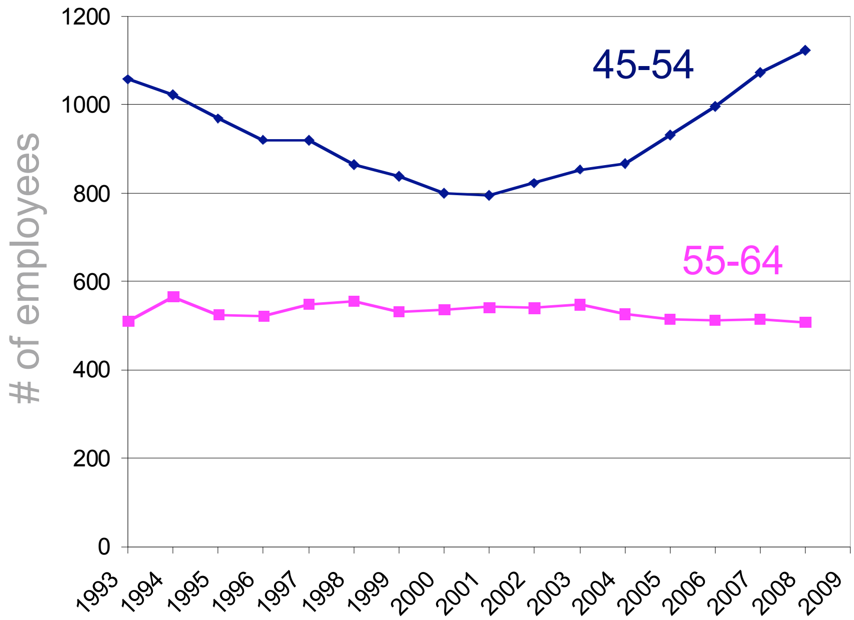
Opposition among Gen Y Hispanics is higher

39%

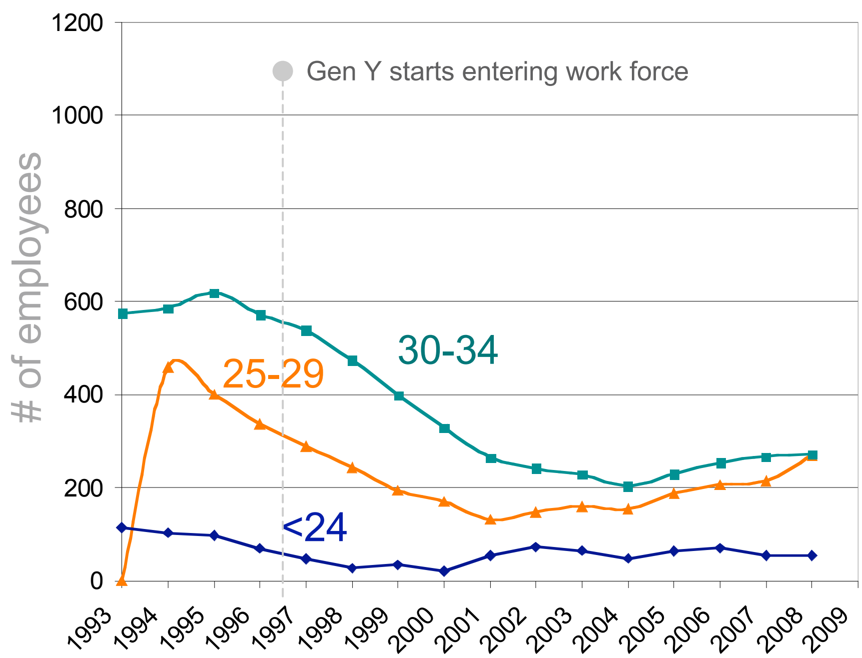
39% believe that nothing worthwhile has come out of NASA

And maybe that's because NASA is not engaging Generation Y

For example, here's the profile at NASA Johnson Space Center for the workforce ages 45-64…



… compare that with the profile of the younger workforce ages <34.



If our generation is asked to pay the majority of the tax bill for the vision for space exploration, ***we need to be engaged in NASA's mission.***

03 Rules of Engagement

So how do you reach an

entire generation

with a brand and message?

First, better understand the audience

Then focus on getting us **interested** again

Our generation is not interested because:

We don’t see the point.

We don’t understand the facts.

We can’t participate.

Instead of *telling* us what you want us to hear …

Facilitate a discussion with Gen Y and allow us to participate in the NASA mission

Share a compelling story

Touch our lives in ways familiar to us.

Utilize “social media”

Spark <u>conversations</u>

But *please* be timely

Reclaim an image as a *leader of innovation*.

What would an innovative,collaborative, participatory NASA look like to us?

Here's a few possible future headlines.

"Explorers Hired: NASA's recruiting advantage"

"What My Teenager Taught NASA About Marketing"

"NASA uses social media to improve public image and reach target audiences"

"Open innovation leads to budget savings and improved reliability of Constellation spacecraft"

"2 million Digg votes for latest NASA press release"

"NASA flattens organization structure and improves innovation"

"NASA openness spins off into the first private spacecraft to land on the moon"

NASA employs the smartest engineers in the world to solve its toughest problems using collaborative innovation

Astronaut twitters from Space during EVA

"NASA enjoys increases visibility, credibility, and audience exposure"

"NASA uses persona based approach to tell its story"

"NASA switches back to Macs"

"Employees awarded with new incentives to innovate at NASA"

"Students from elementary school in Nebraska control Mars Rover from classroom"

What does your local Gen-Y'er think about NASA's future?

When we asked a local Gen-Y'er what she thought about this image:

she commented:

"Hey, that'd make a great T-shirt!"

We couldn't agree more!

There are a number of things that NASA is doing that are on the right track!

04 The Challenge

By no means is this "the answer"

…after all, who are we anyway?

Just some Gen Y-er's who got hooked by the NASA bug and want to help.

But we've done a lot in 4 months…

Co-op Alumni Mentoring
Spoke to several management teams about Gen Y (10+)
Created the Flat NASA Experiment Blog
Created the leadership forum
Inspired public regarding NASA careers using Facebook
Established connections at Rice University
Developed this presentation
Outreach. Lots of outreach
Developed Co-op Advanced Planning Team (CAPT)
Collaborated with Wired Magazine on Article Concept
Connected NASA to Twitter
Facilitated the JSC PAO New Media Project with CAPT
Led the planning of Yuri's Night Houston 08

With only 4 people.

There isn't one ultimate communications strategy to solve NASA's problems once and for all.

…it'd be a lot easier if there was.

So the challenge is to take this and create new ideas.

Because the NASA we want to work for and connect to is like us:

Collaborative

Creative

Open

Timely

Bold

Innovative

Participatory

Connected

Purposeful

Exciting

But we – our generation – want to be a part of the solution.

Because space exploration is the future.

And it is OUR future.

Everyone's future.

References

- Center for Cultural Studies and Analysis. *American Perception of Space Exploration: A Cultural Analysis for NASA*. Philadelphia, PA: Center for Cultural Studies & Analysis, 2004.
- Hopkins, Robert. *Strategic Communications Framework: Implementation Plan*. Washington, DC: National Aeronautics and Space Administration, 2007.
- Space Foundation. Space Awareness Initiative. *America's Spacepoll: An Annual Research and Analysis Project*. Colorado Springs, CO: Space Foundation, 2000.
- Dittmar, Mary Lynne. Engaging the18-25 Generation: Educational Outreach, Interactive Technologies, and Space. Dittmar Associates Inc. Houston, TX
- Smith, Tom. Trends in National Spending Priorities, 1973-2006. General Social Survey. National Opinion Research Center. University of Chicago
- NAS Insights. *Generation Y: The Millennials.* NASA, 2006.
- Kohut, Andrew. *How Young People View Their Lives, Futures and Politics, A Portrait of "Generation Next".* The Pew Research Center, 2007
- Rasmus, Daniel W. The Next-Generation Workforce and Project Management. Academy Sharing Knowledge (ASK) Magazine, Fall 2007.
- NAS Recruitment Communications. *Generation Y. The Millenials* www.nasrecruitment.com/TalentTips/NASinsights/GenerationY.pdf, 2006
- Zelon, Barbara. *Conversation Constellation Strategies*. Houston, TX: National Aeronautics and Space Administration, 2007.
- Live Birth Data collected from http://www.infoplease.com/ipa/A0005067.html.

Taber MacCallum *Paragon Space Development Corp.*

Mr. MacCallum is a Paragon co-founder. Mr. MacCallum was the Principal Investigator on four microgravity experiments on the US Space Shuttle, the Russian Mir Orbital Station and International Space Station using Paragon's Autonomous Biological Systems, and has supported numerous other biological experiments on the Space Shuttle and International Space Station. The four-month Mir experiments produced the first animals to have completed their life cycle in microgravity and the first aquatic plants to be grown in space. Mr. MacCallum is a co-designer and patent holder for the Autonomous Biological System. He was the design lead for the Jet Propulsion Lab Mars Greenhouse Experiment Module (GEM) payload, and Mars GEM payload ECLSS. He is presently involved in the design of life support and thermal control systems for commercial manned suborbital spacecraft, a novel Mars space suit portable life support system technology funded by NASA, as well as hazardous environment life support technology development for the US Navy divers in which he is the test diver.

Mr. MacCallum was a member of the first two-year mission living and working inside Biosphere 2, a three-acre materially closed ecological system, containing seven biomes, which supported the life of the eight human inhabitants. It was designed for research applicable to environmental management on Earth and the development of human life support for space.

He was responsible for the design, implementation and operation of the atmosphere and water management systems as well as the self-contained paperless analytical laboratories for Biosphere 2 and its Research and Development Center. He has been granted a patent for his design of the Biosphere 2 air sampling and analysis system. Mr. MacCallum has been involved in numerous analytic efforts including a Soviet BioSatellite project and a marine microbial sampling project. Mr. MacCallum also served as Safety Officer and Assistant Medical Officer on the Biosphere 2 Resident Research Team. He has published numerous papers resulting from his work at Biosphere 2, on space related issues, medical issues and on the experience of living and working in an Isolated Confined Environment.

Mr. MacCallum has worked at every level of command on a research vessel, sailing to over 40 ports and over 30,000 miles around the world. Training in Singapore, he became certified as a Dive Controller and Advanced Open Water Diving Instructor. He served as Dive Master for a project to reintroduce two captive dolphins to the wild, ship salvage operations, and specimen collecting expeditions in every ocean and most of the world's seas.

Asked to talk about

- Entrepreneurial Opportunities in Lunar Development
- Personal experience with what would be needed to live on the moon sustainably in the short-term
- Closed loop life support (2 years and 20 minutes in Biosphere 2)
- Life support and Medicine in Personal Spaceflight.
- How an entrepreneurial company can play vital roles today to enable lunar development

"Next Generation" of space leaders

(mini ISU)

Project Fundamentals:

The Right –

- Time
- Place
- People
- Technology

- Resources
- Business Model / Plan
- Ideas / Vision
- Leadership

The ugly questions -

- What are the requirements of a great vision / idea?

- What makes great leadership?

The Idea

- It is hard to make a business case if you start with a place rather than a market
  - Generally we are interested in space and technology before business
  - What we think is cool is irrelevant to most people, so business plans fail…… It's hard being geek.
- Technical achievements don't broadly inspire people by themselves, unless linked to something like a national imperative.
  - The engineers are salivating again….
  - Engineers appreciate engineering
  - The "back on track" idea that America was ever on track toward manned exploration of the solar system is patently false, we were never on such a track.

(Parenthetical Comment)

- Using space exploration to symbolically maintain technical prowess is the bottom rung of national reasons for a space program (but a good one).
- Apollo set the bar:
  - *If we can but a man on the Moon we can “fill in the blank”*.
  - Being an Astronaut is right up there with being President, Santa Claus, or a Fireman.
  - It must be audacious in it’s conveyance of a sense of pride in what we, as a civilization, can reach for.
  - More important now than ever
- National pride does not make for a good *commercial* business plan

R & R

- If you have a good *risk / reward* business plan that can attract funding, then you have already met the best requirement of a commercial idea.
  - Not many such lunar business plans exist, many are a dead start, or failed.
  - Google is trying to inspire one of them, the media / inspiration / jumpstart ….

The vision

- A media content based business plan is essentially selling the same thing as what could be a compelling national vision for space exploration.
  - Discovery, inspiration, science, wonder, images
- These types of visions obviously fail if they don't inspire

The vision-thing as part of a business plan

- Hubble inspires and has general support
  - The support surprised many people
- Discovery, inspiration, science, wonder, images
  - A quest to answer a fundamental question that informs us about who we are
  - The origin of life it's self.
- Finding evidence of life off the Earth calibrates who we are

Biosphere 2 as a case study

- Less that 10% of the popular interest in Biosphere 2 was actually space related
- It touched a chord in people because it addresses a fundamental question about life and our biosphere.
  - *Can we build an artificial biosphere that will sustain human life?*
  - What is a biosphere?

Biosphere 2 as a case study (cont.)

The “will it work” question leads to many compelling corollaries:

- Will the crew go crazy?
- Crew Psychology = Reality TV!
- A tool for environmental science
- Survival in remote hostile places (including space)
- Environmental interest / global climate change
- Science: ecology, biology, “biospherics”
- The word “biosphere” was not in the American lexicon

Biosphere 2 as a case study (cont.)

- Even a scary idea (Would you do it?)
- Idea that teachers still use to explain how life on this planet works, how our Earth’s biosphere works
- The vision of Biosphere 2 helped inform us about humanity and the world around us
- It had people on a journey with a purpose
- Over 20 years after we introduced the idea I still give talks about it

Biosphere 2 as a case study (cont.)

- Biosphere 2 was like a Rorschach inkblot test; people saw different things in it, and were attracted for different reasons.
- **A measure of the success of a vision (be it a commercial application or government program) is it's recognition and popular appeal.**
- Biosphere 2 was carried in every major media outlet before we even broke ground.
- It was relevant to the time in history
- It must be a powerful Idea / Vision or it can not make money or inspire people.

Are we alone?
Where do we come from?

Why are we going to the Moon?

- Harness the instinct to explore, a daring journey of discovery?
- We set out to explore the solar system in search of evidence to explain its own origin, the search for the origin of life?
- Does the vision incorporate relevancy to the time?
- Does it seem impossible to most people?
- Why it is compelling? Even on Mars, going for the sake of going is not enough.

????

If the vision or idea is central to the success of your business plan, just because it is cool and in space does not mean it is be compelling to a broad audience (market).

We are generally a bad judge of what is cool

Many projects have gotten this far and failed

The Right –

✓Time

✓Place

✓People

✓Technology

✓Resources

✓Business Model / Plan

✓Ideas / Vision

• Leadership

Implementation
(universally underestimated)

- This is where projects that met every other criteria died.
- Even after having the money, time, technology, etc. etc.

Was it the basics?

- Best people in the right seats on the bus?
- Good handle on resources?
- **Leadership and staff are well grounded in the physics and engineering?**
- Made and documented decisions / assumptions?
- Goal oriented? Set goals and targets and then let the best minds hit them?
- Systems Engineering? Got the requirements down and maintained a steady course of progress towards hitting them?
- Too much time looking for the "killer innovation" that makes everything possible?
- The Growth? Believed your own press releases?

What went wrong?

- Were they a great judge of people and talent?
- A developer of people and self-sustaining organizations?
- Understand the program as a human endeavor?
- Did they pick and develop excellent managers?
  - Dependency on central command?
- Developed a good business plan and stuck to it?
  - Because of the almost mythical aspects of space exploration, many people get caught up chasing dreams instead of pragmatic success.
- Continuously learning and adapting tactics?
  - The space market is like most relatively new markets, an ever-shifting landscape

Communicate well?

The problem with communication is the illusion that it occurred.

Assured access to validated information?

Did they Follow the Data?

…the truth (data) will set you free

Jesus in John 8:32

Questions Authority?

The deepest sin against the human mind is to believe things without evidence.

Thomas H. Huxley (defender of Darwin)

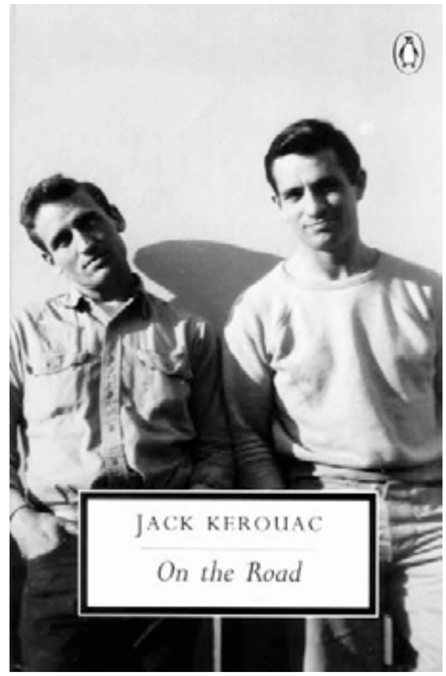
See Reality?

Kerouac is one of the most influential "*leaders*" of our time

Created the Beat Generation with Burroughs and Ginsberg

They gave us a unique unvarnished view of our world, the truth of which helped set generations free after WW2

(The Role is now as museum piece)



Neal Cassady and Jack Kerouac

EGO or HUBRIS?

- Become identified with the project or position.
  - Your estimate of self worth is tied to the outcome of the project
- "Never let your ego get so close to your position that when your position goes, your ego goes with it." - General Colin Powell
- Space is not forgiving
- A humble endeavor

The **Achilles Heel** of leadership is emotional intelligence and maturity

- The ability to perceive, manage, express, and utilize emotions
- The innate potential to feel, use, communicate, recognize, remember, describe, identify, learn from, manage, understand and explain emotions.
- An ability, capacity, or skill to perceive, assess, and manage the emotions of one's self, of others, and of groups.
- The ability to monitor one's own and others' feelings and emotions, to discriminate among them and to use this information to guide one's thinking and actions.

- **2004 Army Research Institute request for proposals**

- OBJECTIVE: Validated measures to assess emotional intelligence and materials to train and develop related competencies.

- DESCRIPTION: Broad societal changes have influenced the nature of work within both the military and the civilian sector and carry implications for the identification and development of skill sets required to function effectively under high-stress and other emotionally-laden circumstances. These conditions are sometimes associated with interpersonal transactions but may also emerge as reactions to fast-paced, high-demand events and situations. Since 1990, emerging psychological conceptualizations have theorized that the ability to perceive, manage, express, and utilize emotions has profound ramifications for understanding and supporting human cognition and performance,…

Emotional Intelligence

- Found to be a significant predictor of success
- "New field"
- Principal reason why Americans are typically bad negotiators
- Poor emotional education in America
- Darwin noted the importance of emotional expression for survival and adaptation.
- **But Aerospace is a technical field!**

The Knack

False Stereotype?

- Geek
  - MS Word lists the synonyms as **drip** and **bore**
- Nerd
- The classic socially inept engineer

Gnothi Seauton (Know Thyself)

- How do we get E.I. and find it in others?
- Training (settings that allow self observation)
  - Leadership Training **ISU SSP**
  - **Sports**, Quest, Travel
  - Observe Survival Reactions

- Determine Attitude
  - Put yourself or prospective hires / team members in high-pressure and social settings
  - Self aware - Self conscious - Mindful
- Valid observations made of behavior under stress is the surest rout to knowing thyself.
- **The unexamined life is not worth living.**

Questions?

Robert Richards *Odyssey Moon Limited*

Dr. Robert (Bob) Richards is the Founder and CEO of Odyssey Moon Limited, a commercial lunar enterprise based in the Isle of Man and the first official registrant in the $30M Google Lunar X PRIZE competition. He is also the Director of Space Technology at Optech Incorporated of Canada, where he presided over the first commercial lidar scanner flown in space as well as the first meteorological lidar flown to another planet aboard the NASA Phoenix Mars Lander. Bob studied aerospace and industrial engineering at Ryerson University; physics and astronomy at the University of Toronto; and space science at Cornell University where he became special assistant to Carl Sagan. A Founder of the International Space University, SEDS, and the Space Generation Foundation, Bob is a strong advocate of the NewSpace movement and has been a catalyst for a number of commercial space ventures. He is the recipient of four international space awards: the K.E. Tsiolkovski Medal (Russia, 1995), the Space Frontier "Vision to Reality" Award (USA , 1994), the Arthur C. Clarke Commendation (Sri Lanka, 1990) and Aviation & Space Technology Laurel (USA, 1988). He is a contributing author of "Blueprint for Space", published by the Smithsonian Institution in 1992, and "Return to the Moon", published by Apogee Books in 2005. In 2005 Bob received a Doctorate of Space Achievement (honoris causa) from the International Space University for "distinguished accomplishments in support of humanity's exploration and use of space."


X PRIZE - 2004
ODYSSEY
MOON
Google
LUNAR X PRIZE


X PRIZE - 2004
$10 Million Race Into Space for the X-Prize
Discover
CLONING EXTINCT ANIMALS
POPULAR SCIENCE
NASCAR WITH ROCKETS!
AIR&
HONEYMOON IN SPACE
TIME
THE MOST AMAZING
inventions
OF 2004
Ten Million Dollars and
10,000,000.00
ODYSSEY
MOON
Google
LUNAR X PRIZE

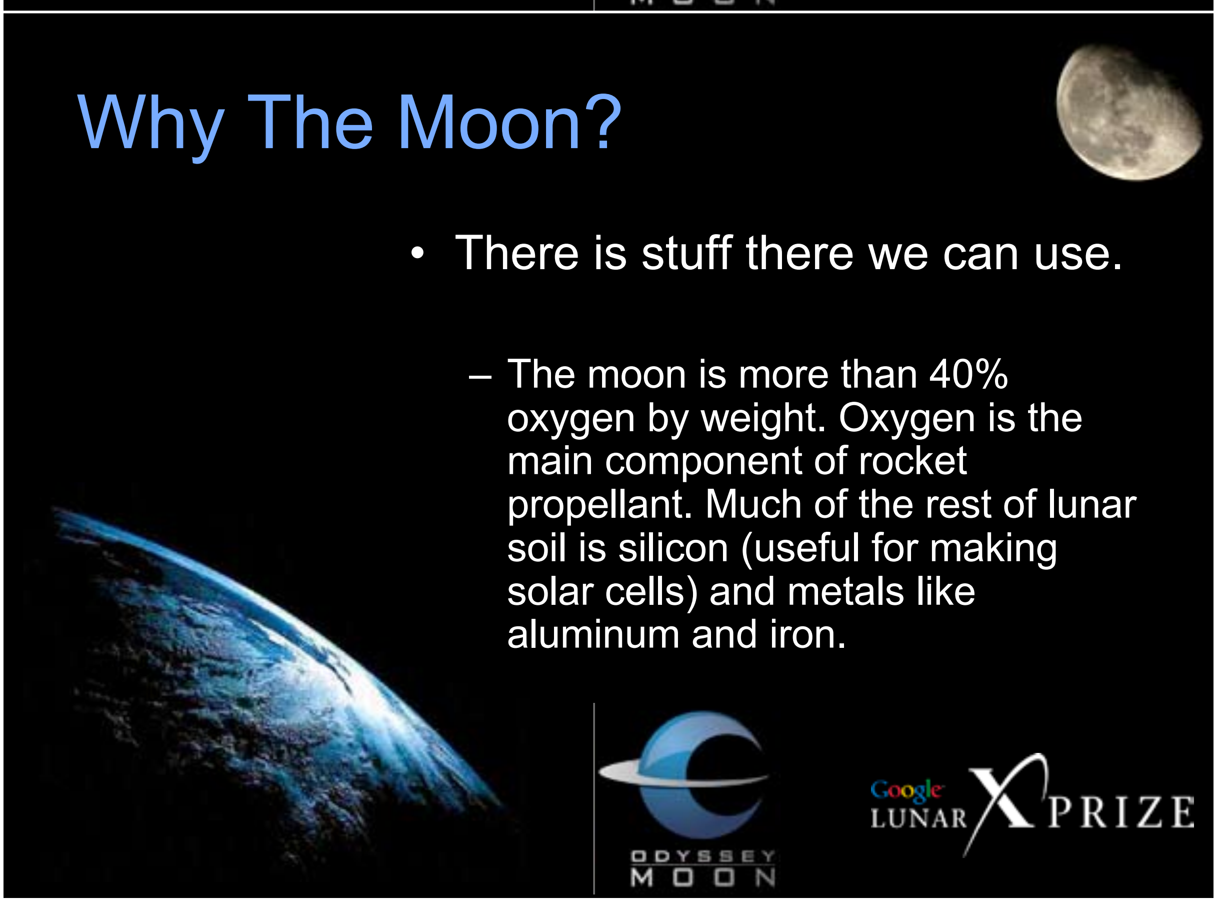

X PRIZE FOUNDATION
What's NEXT ?
"1927 - First Non-Stop Transatlantic Flight Orteig Prize"
"1961 - First Man In Space"
"1969 - First Man On The Moon"
"2004 - First Manned Private Spaceflight Ansari X PRIZE"
Revolution Through Competition


X PRIZE FOUNDATION
September 13th, 2007
Google LUNAR X PRIZE
What's NEXT ?
"1927 - First Non-Stop Transatlantic Flight Orteig Prize"
"1961 - First Man In Space"
"1969 - First Man On The Moon"
"2004 - First Manned Private Spaceflight Ansari X PRIZE"
Revolution Through Competition


December 6th, 2007
OFFICIAL TEAM
Google LUNAR X PRIZE
ODYSSEY MOON
ODYSSEY MOON
Google LUNAR X PRIZE


Why The Moon?
• We live in a unique two world environment - the Earth-Moon System.
– the Moon is a stepping stone to the rest of the Solar System and a source of solutions to some of the most pressing environmental problems that we face on the Earth.
ODYSSEY MOON
Google LUNAR X PRIZE


Why The Moon?
• The Moon is like an 8th continent, rich in resources, floating just offshore.
ODYSSEY MOON
Google LUNAR X PRIZE


Why The Moon?
• There is stuff there we can use.
– The moon is more than 40% oxygen by weight. Oxygen is the main component of rocket propellant. Much of the rest of lunar soil is silicon (useful for making solar cells) and metals like aluminum and iron.
ODYSSEY MOON
Google LUNAR X PRIZE


Why The Moon?
• The Moon is the closest source of materials for doing anything in space.
– it's 22 times easier to launch stuff from the Moon than from the Earth.
ODYSSEY MOON
Google LUNAR X PRIZE


Why The Moon?
• We Can Create New Safe, Clean Energy for Planet Earth
– Clean solar energy can be sent from space to the earth with solar collectors in high Earth orbit made from lunar materials.
– A single solar power satellite could power a major Earth city without CO2 or other pollution.
ODYSSEY MOON
Google LUNAR X PRIZE


Why The Moon?
• It's only 3 days away
– The moon's close proximity to the Earth makes it a great place for humans to learn to live and work in space while still having frequent rescue and return opportunities.
ODYSSEY MOON
Google LUNAR X PRIZE


Why The Moon?
• We Can Back-up the Biosphere
– The Moon provides an ideal place to backup the biosphere and the accumulated knowledge of mankind.
ODYSSEY MOON
Google LUNAR X PRIZE


Why The Moon?
• We Can embrace the Moon into Earths' economic and social spheres
– By expanding the solution set to include resources outside the Earth's biosphere we can solve seemingly intractable problems of energy and the environment and enable the remediation of the Earth.
ODYSSEY MOON
Google LUNAR X PRIZE


Odyssey Moon Limited
• Over a year in the making
• Long term view to lunar commerce
• Google Lunar X PRIZE a catalyst
• Based in Isle of Man
– Favourable finance & tax regime
– Innovative space legislation
– Not subject to US ITAR
ODYSSEY MOON
Google LUNAR X PRIZE


OM Goals & Team
• Become the first private enterprise to reach the surface of the Moon
• Be the first to market ongoing lunar mission products and services
• Win the Google Lunar X PRIZE
• Experienced executive team
• Well known prime contactor (MDA)
ODYSSEY MOON
Google LUNAR X PRIZE


OM Founding Directors
• Dr. Robert (Bob) Richards, CEO
– Co-Founder, ISU
• Dr. Ramin Khadem, Chairman
– Former CFO, Inmarsat
• Mr. Christopher Stott
– CEO, ManSat Ltd.
• Mr. Michael Potter
– Managing Partner, Paradigm Ventures
ODYSSEY MOON
Google LUNAR X PRIZE


Board of Advisors
• Dr. James D. Burke (JPL retired) – NASA Lunar Ranger Project Manager
• Dr. Wendell W. Mendell – Planetary Scientist
• Dr. Louis Friedman – Founder and Executive Director, The Planetary Society
• Dr. J. Buckner Hightower – founding director, Excalibur Almaz Limited; Trustee, Heinlein Prize Trust
• Mr. Jon Lomberg – Artist; Chief Artist, COSMOS Television Series
• Dr. Jean-Luc Jossett – Director, Space Exploration Institute
• Mr. Charles M. Chafer – CEO, Space Services Inc.
• Dr. David Miller – Professor, University of Oklahoma
ODYSSEY MOON
Google LUNAR X PRIZE


Prime Contractor: MDA
Dr. Christian Sallaberger
Vice President with MDA's Information Systems Group
• Canada's largest space company
• Represented on the OM Board
• An experienced company with substantial space heritage in providing robotics on the Space Shuttle and International Space Station, and more recently for satellite servicing and planetary exploration
ODYSSEY MOON
Google LUNAR X PRIZE


OM Strategy – Next steps
• Promote diverse sustainable business models
• Catalyze Earth-Moon economy & focus on a new frontier for benefit of mankind
• Lower risk through multi-national agreements and business arrangements
• Seek synergies between governments and private consortiums
• Involve international players – "unity thru diversity"
ODYSSEY MOON
Google LUNAR X PRIZE


ODYSSEY MOON
History Restarts
2007.12.06
Google LUNAR X PRIZE

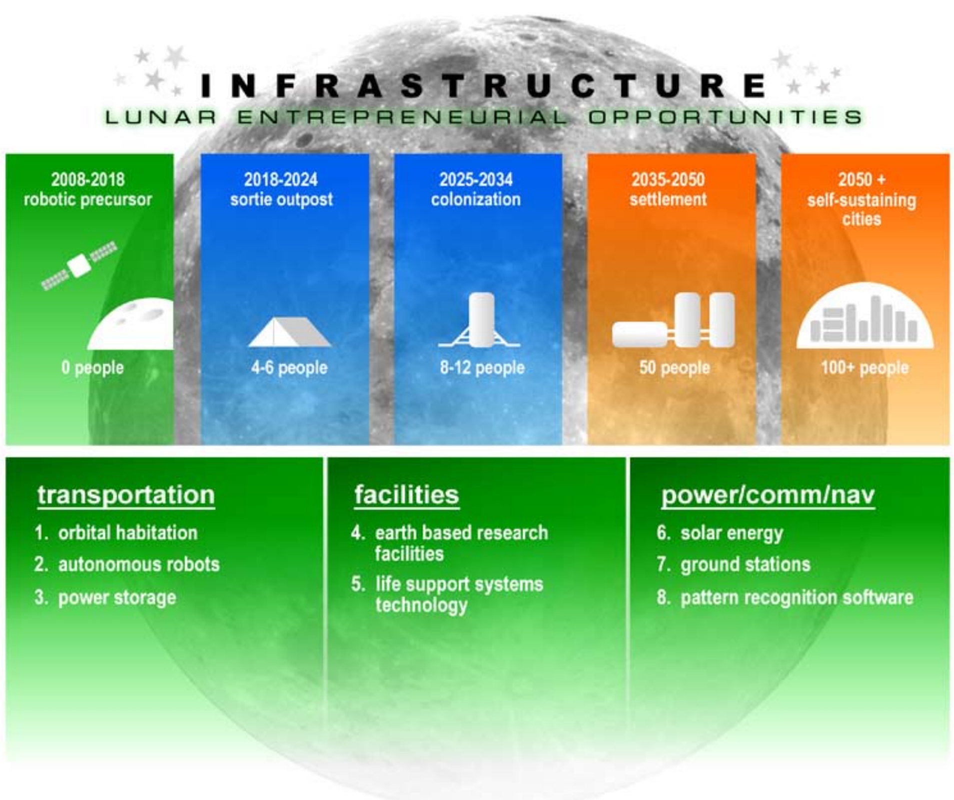
NGEC-2 Working Group Reports

Infrastructure, Utilities, and Consumables

Moderators:
Nicholas Skytland
Marshal Blessing
Rivers Lamb

Working Group:

Kelley Atkinson	Shuonan Dong	Sharon Jefferies
Brian Shoening	Justin Thomas	Jennifer Bailey
Joshua Scherbenski	Garret Fitzpatrick	Delia Santiago
Frank Centinello	Mike Lindsay	Ezinne Uzo-Okoro
Alex MacDonald	Jeffery Candiloro	Chris Nelson



Background and Scope

"Infrastructure" is a broad term referring to all physical capital that enables Lunar development. The "consumables" are the items that are required for development and sustainability of a Lunar community (i.e., water, fuel, and oxygen). The consumables are provided as a service by "utilities," or companies that manage the day-to-day collection and distribution of the consumables. In this setting, the infrastructure is the physical framework that is required to enable the utility service, mainly items that require high capital investment (i.e., mining machines, roadways, and power-generation systems).

Future Lunar operations will benefit if they can draw upon a foundation of infrastructure, utilities, and consumables that have previously been established. This infrastructure will reduce mission cost and allow for longer mission durations. There is, therefore, the potential for NASA to provide basic infrastructure to support private operations, as well as business opportunities for private business to supply infrastructure and consumables to NASA or other space companies.

Near-Term Infrastructure Markets

Following is a list of near-term commercial opportunities as identified by the Infrastructure, Utilities, and Consumables working group. The full list of near-term (less than 10 years), mid-term (10-20 years), and far-term (20 years plus) opportunities from each group can be found in the Appendix A time-phase analysis table. Appendix B has a market analysis for each near-term opportunity, and Appendix C has identified risks for each. Additional discussion and details are provided below for the items identified as special areas of imminent focus. Bolded phrases in the text indicate the near-term opportunities as listed in the Appendices B and C, for reference.

Transportation

Autonomous Robots/Rovers: Autonomous mobile robots will pave the path for Lunar surface exploration, science, and commerce. This ever-increasing market already includes the Google X PRIZE teams, international space programs, and NASA. Commercial ventures will take advantage of existing commercial robotic hardware platforms (rescue, drilling, and imaging) to minimize development costs and sustain profitable business. Specific near-term opportunities include:

I.1 **Terrestrial rover sandboxes:** Extreme/remote environment rovers for education, entertainment, and marketing. For example: Antarctic rover controlled in a classroom, store, or website.

I.2 **Exploration Rovers:** Rovers for Lunar imaging, navigation, and surface mapping.

I.3 **Tele-Operated Repair Robots** (à la Robonaut): For terrestrial and LEO operations, robots capable of repairing equipment/structures in extreme terrestrial and LEO environments.

Mobile Platforms

I.4 **Small-scale people and cargo movement capability:** Platforms to move people and/or cargo on the Moon's surface and in extreme terrestrial environments.

Surveying and Road Development

I.5 **Surface topography mapping:** Identification, development, and mapping of road networks, and surveys and site preparation for construction. The mappings can also be used to facilitate educational and entertainment opportunities using Lunar imagery.

» Imaging instruments: Development of high-resolution instruments/cameras for surface mapping and surveying, which can be used both for Earth and the Moon.
» Surface surveying: Earth-based analysis of imagery to identify potential landing zones, roads, and outpost and settlement sites and -based surveying to mark roads and facilitate outpost and settlement construction. This may include the development of small survey support robots that can be used in remote areas on Earth.
» Road maps and site survey maps: Generation of maps depicting road networks, Lunar sites of interest, resource locations, inhabited areas, etc. (if we map it on Earth, someone may want something similar for the Moon).

Fuel Depots

I.6 **Development of fuel depot systems for fuel supply in orbit.**

Orbital Habitation/Transfer Station: Development of living spaces to support travelers during transit to the Moon, which also facilitate stays in LEO and low Lunar orbit (LLO). In the short term, such stations could run as hotels in LEO for tourism and advertising.

I.7 **Orbital hotels in LEO:** Orbiting habitats can provide a node in the trans-Lunar transportation infrastructure by serving as a transfer station for humans and cargo from Earth to LEO, LEO to LLO, and LLO to Lunar surface. Building orbiting habitats for LEO provides the first step in the infrastructure; these habitats can be used as a destination for space tourism and a research location for universities. Research and development that goes into developing these orbital habitats also ties into Lunar surface habitation applications and could also be sold back to government agencies.

Power Recharge Station

I.8 **Electric-car charging station:** Network of dedicated terrestrial stations for recharging electric cars.

I.9 **Stations for dedicated network of terrestrial stations.**

Launch/ Landing Facilities

I.10 **Terrestrial launch/landing facilities:** Development of terrestrial and Lunar launch and landing facilities, including facilities to support humans in transit and facilities for warehousing and shipping of cargo. Short-term focus would be mainly terrestrial-based facilities.

Habitability

Design

I.11 **Human factors,** including sound/acoustics. Government would manage system integration.

Food

I.12 **Food grown in habitat** (not including food brought in by external sources). For example: Johnson Space Center (JSC) Advanced Life Support Food Systems.

Storage

I.13 Small-scale **storage/cargo systems**.

Chemical Consumables: Raw chemical materials for creating water and air for habitation.

I.14 **Delivery from Earth, distribution, and storage of chemical consumables.**

Life support systems technology: Numerous life support systems are needed to maintain a sustainable human habitat in any isolated environment. In particular, entrepreneurial opportunities exist on Earth to develop closed-loop waste management and water-filtration systems that operate in isolated environments anywhere on the planet. Cities, rural communities, and isolated research labs in both technologically advanced and impoverished areas could all benefit from clean, efficient systems to manage and recycle solid and liquid wastes and provide potable and non-potable water for sustained human survival. The development of these technologies has grown quickly in the last few years, and opportunities for spinning off these technologies for Lunar development purposes would be abundant.

Water Infrastructure

I.15 **Delivery from Earth, distribution, and storage of water,** including water filtration, purification, circulation, and infrastructure.

Air Systems

I.16 **Air systems (composition and pressure): Ionic membrane, CO2 control systems, and mechanical filtering of dust.**

Waste Management: Both organic and nonorganic waste management, both cycled within the habitat and recycled outside the habitat.

I.17 **Piping, plumbing, and external/ internal recycling.**

Space Suits: Suits used for short- and long-range extra-vehicular surface activities, including all suit subsystems and survivability equipment.

I.18 **Breathing air, cooling, navigation systems; umbilical connections; and crew survivability equipment.**

Thermal Control Systems

I.19 **Active/passive thermal control systems.**

General Equipment

I.20 **Furniture, exercise, lab equipment; appliances; tools; supplies; clothing.**

Power, Communications, and Navigation

Power: The ability to capture and store energy for transportation to the Moon and on the Moon is an important aspect of Lunar commercialization. Being able to capture solar energy and convert it to mechanical energy will reduce the cost of missions through reduced launch mass and increase the sustainability of surface missions through continuous energy supply. Development of this capability is essential to the new wave in automobiles for on-Earth transportation. A co-development of this technology today will broaden its application, reduce cost, and introduce new ideas and ways of thinking to both industries.

I.21 **Solar power generation/cryogenic storage:** Development of higher-efficiency photovoltaics has application and high demand in today's current market. This technology would be used to supply energy to spacecraft, equipment, outposts, and eventually settlements. Improved solar cell technology is a critical technology for long-term Lunar development. More importantly, improved solar cell technology is needed to serve energy markets on Earth. Partnerships should be pursued with existing "Fourth-Generation" photovoltaic companies Xsunx, Konarka Technologies, Inc., Nanosolar, Dyesol, and Nanosys.

Communication

I.22 **Private expansion of NASA's Deep Space Network** (DSN). Private industry could build and operate the next generation of antennae for NASA's DSN. The network is currently at or near capacity and it is expected that by 2020 it will need to communicate with twice as many missions as in 2005. Deploying more advanced, ground-based communications infrastructure is the most cost-effective way to both continue with current global space exploration and provide the high-bandwidth channels required for Lunar exploration and exploitation, both private and public.

Navigation

I.23 **Lunar navigation via high-resolution images and pattern-recognition advancements.** Infrastructure could be used for position and velocity determination of spacecraft. The LEO satellite could be used for launch and LEO operations, Earth ground supplemental DSN for Earth-to-Lunar transportation, and high-resolution imagery and pattern recognition development for Lunar landing and Lunar surface operations. Earth ground supplemental DSN could be developed for Earth-to-Lunar transportation and high-resolution imagery and pattern-recognition technology for Lunar landing and Lunar surface operations.

The development of multi-source information fusion and pattern-recognition algorithms is essential for developing Lunar navigation infrastructure. This technology, though largely theoretical, has a wide variety of terrestrial applications in addition to navigation, including law enforcement, pathology, genomics, traffic management, and artificial intelligence.

Facilities

Earth-based Facilities for Research and Development: facilities of new and updated technologies relating to the following areas necessary for sorties to the Moon. Testing and development of technologies relating to the following areas is necessary for sorties to the Moon and for brokering international and small business access to U.S. Government facilities for this research: vibration, radiation, thermal, or microgravity testing, dust mitigation, and materials testing. This research is already being done in analog environments such as parabolic flight, Devon Island, NASA Extreme Environment Mission Operations (NEEMO), and Antarctica.

I.24 **Radiation testing facilities**

I.25 **Thermal testing facilities**

I.26 **Microgravity testing facilities** (including parabolic flights)

I.27 **Vacuum testing facilities**

I.28 **Dust testing facilities**

I.29 **Vibration testing facilities**

I.30 **Facility brokering:** International and small company access to NASA facilities for material/scientific research could be brokered.

Space/Lunar-based Research

I.31 **Orbital habitats** at LEO/Lagrange points need to be developed. Researchers could buy time on the International Space Station (ISS) for their research, fulfilling the original intent of the ISS.

I.32 **ISS centrifuge:** A centrifuge was in the original ISS plans, but has been cut from the budget. A private business could install and operate the centrifuge on the ISS.

Construction Materials

I.33 **High strength-to-weight materials:** High strength-to-weight, (e.g., lightweight and strong), cheap materials could be developed.

I.34 **Memory-shape materials:** Memory-shape materials could be folded and stored for transportation to the surface of the Moon, and then regain their original size and shape when unpacked.

I.35 **Radiation protection materials** could be developed.

Construction Tools/Equipment

I.36 **Lightweight tools:** Hand tools could be developed to be used for infrastructure construction, in laboratories, and for maintenance.

I.37 **Simple construction rovers:** These rovers would aid in construction of habitats, facilities, etc.

Mining

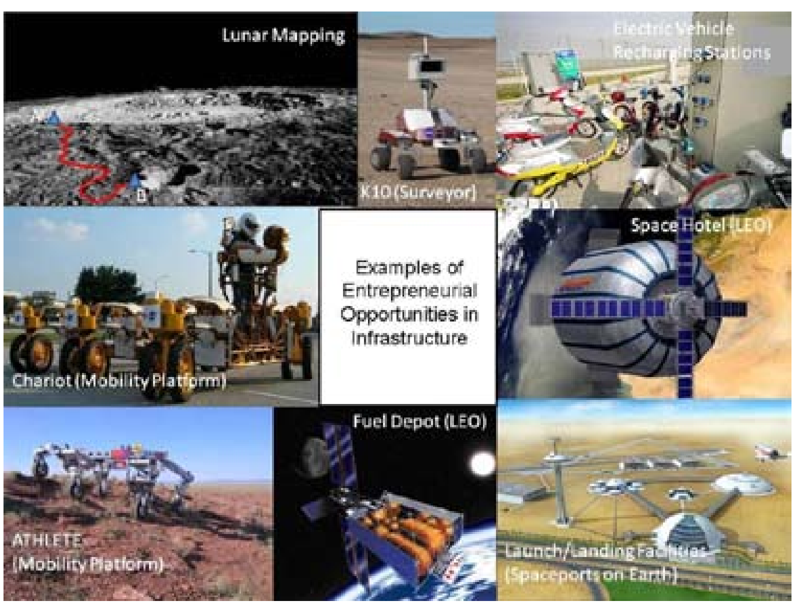
I.38 **Regolith excavation/mass-moving:** Material from the site that is to be developed needs to be excavated and removed.

I.39 **Sampling and drilling** will need to be performed.

I.40 **Dry mining** will need to be performed.

References

http://robonaut.jsc.nasa.gov/
http://www.nasa.gov/multimedia/imagegallery/image_feature_748.html
http://www.thecherokeean.com/news/2008/0130/Front_page/004.html
http://en.wikipedia.org/wiki/Lunar_Reconnaissance_Orbiter
http://en.wikipedia.org/wiki/Chandrayaan
http://www.planetary.org/explore/topics/space_missions/kaguya/instruments.html
http://ic.arc.nasa.gov/projects/haughton_field/
http://thefraserdomain.typepad.com/energy/2007/10/uk-to-get-250-e.html
http://www.futurepundit.com/archives/004733.html
http://msp.gsfc.nasa.gov/tdrss/oview.html
http://www.garmin.com/
http://www.magellangps.com/
http://www.glonass-ianc.rsa.ru/



Services

Moderators:
Trond Krovel Matt Reyes

Working Group:
Natacha Chough Amy Connors Steve Wilson
Kimberley Clayfield Michael Brett Brandt Pyles
Ashwin Lalendran

Background and Scope

The Services working group identified existing services that are terrestrial analogs to those required during Lunar development. These analogs have the common elements of international cooperation, industry-driven standardization, and open labor markets. The group defined "service" as the continuous provision of labor, space, or equipment useful to others. A commercial service opportunity has an additional value proposition for stakeholders.

The group developed a brief history of services provided to space and Lunar explorers to date, and also accounted for the fact that Lunar services can be based on Earth to support Earth activities such as the design and manufacture of Lunar exploration missions equipment. They can support activities occurring both on and in transit to the Moon. The group defined "astronauts" as any organic, sentient beings off Earth.

Near Term Services Markets

Following is a list of near-term commercial opportunities as identified by the Services working group. The full list of near-term (less than 10 years), mid-term (10-20 years), and far-term (20 years plus) opportunities from each group can be found in the Appendix A time-phase analysis table. Appendix B has a market analysis for each near-term opportunity, and Appendix C has identified risks for each. Additional discussion and details are provided below for the items identified as special areas of imminent focus. Bolded phrases in the text indicate the near-term opportunities as listed in the Appendices B and C, for reference.

Waste Management

S.1 **Space-debris tracking and removal:** It is anticipated that in the future, as space traffic increases, it will become compulsory for all objects launched into space to have a disposal mechanism for the protection of space assets and the space environment. Naturally occurring debris (e.g., meteorites and asteroids) must also be tracked. Also includes recovery of distressed/non-operational vehicles in transit or in orbit to or at the lunar surface.

S.2 **Removal and recycling of waste produced on the Moon.**

Utilities Management

S.3 **Multi-capability robotics** to support or enable missions: Unmanned aerial vehicle (UAV)-type suppliers, mining technology suppliers, and robotics suppliers, e.g. MDA Robotics, Northrop Grumman, and iRobot.

Legal

S.4 **Legal advice for entrepreneurs:** Includes commercial astronauts, space law specialists, consultants, and lobbyists; International Traffic in Arms (ITAR) and other export control advice for international Lunar cooperation; and property rights, commercial law, IP protection, and arbitration for Lunar property issues.

S.5 **Legal advice for legislators**

Operational Support

S.6 **Knowledge store on the Moon:** Aggregated information and distribution to users on the Moon. For example, maps (topography, geology), medical information, user/service manuals, etc.

S.7 **Knowledge store on the Earth:** Aggregation, organization, and distribution of knowledge related to exploration and utilization of the Moon; for example mission data, mapping, and engineering knowledge.

S.8 **Systems engineering and administrative documentation:** Outsourcing of paperwork, optimization of workflow (work shifts in different time zones). Also, robotic services, test services, and launch and flight safety facilitation.

Industry Standards

S.9 **Development accreditation of industry standards,** based on those already created for Institute of Electrical and Electronics Engineers (IEEE) and other similar organizations. Examples: IEEE, education standards, National Space Grant Foundation (NSGF), SpaceTEC, food safety, Advanced Analytical Technologies, Inc. for rapid microbial detection of food/H20 (current commercial partner of NASA Food Technology Commercial Space Center (FTCSC), U.S. Department of Agriculture (USDA), Material Safety Standards, Title 14 Part 25 USC (Aviation Manufacturing Standards), American Society for Testing and Materials (ASTM), Underwriters Laboratories Inc. (UL), engineering technical interface standards, American National Standards Institute (ANSI), Electronic Industries Association (EIA), Underwriters Laboratories, Skandia, Inc., and Canadian Standards Association.

Communication

S.10 **Data and services** including communication service in transit to and at the Moon. For example, Deep Space Network.

S.11 **Spectrum management and regulation** to allow interoperability and noninterference between users of the Moon. On the Moon, local wireless network; spectrum management and regulation; provision of advice and certification to and around the agreed-upon spectrum regulations. For example, consulting services for the use of spectrum and certification of hardware or operations to the spectrum regulations; consulting services; and certification of equipment to the spectrum.

Financial

S.12 **Insurance** (monetary and services) for hardware, mission objectives, and personnel would be necessary in order to manage risk and make services available that would be prohibitively expensive for an individual operator; for example, search and rescue of astronauts, hardware, and robots, reimbursement of cost for equipment lost, etc. Also, inventory trade, Lunar stock exchange, carbon credits, and a bank on the Moon would be necessary. Commercial demand from suborbital flight providers and X-prize participants will accelerate adoption of new services. Partnering to specialize existing services such as Lloyd's of London and Medjet would provide additional confidence in future supply.

Space Traffic Management

S.13 Provision of accurate **navigational systems**, including correction and augmentation, and service to spacecraft en route to, in orbit around, or at the surface of the Moon, and an orbit control management service to spacecraft en route to, in orbit around, or at the surface of the Moon; routing and piloting; and accurate navigation signals, including correction and augmentation.

Cartography:

S.14 Provision of accurate, up-to-date **cartographic data** of the Moon to support surface operations, exploration, and production, possibly including three-dimensional (3-D) terrain models, geological maps, resource maps, etc.

Education and Training

S.15 **New-recruit training** with training standards and accreditation. Examples include

SpaceTEC, which is analogous to Cisco or Microsoft product certification. The most similar requirements would be Antarctic training requirements.

Health

S.16 **Preventative medicine:** Specialist treatment of astronauts and support personnel prior to launch and on-station has significant opportunity for health care specialists. Preventative medicine, including astronaut screening services, has a large terrestrial market. Potential partners include Wyle Labs, NPS Pharmaceuticals, and GSK.

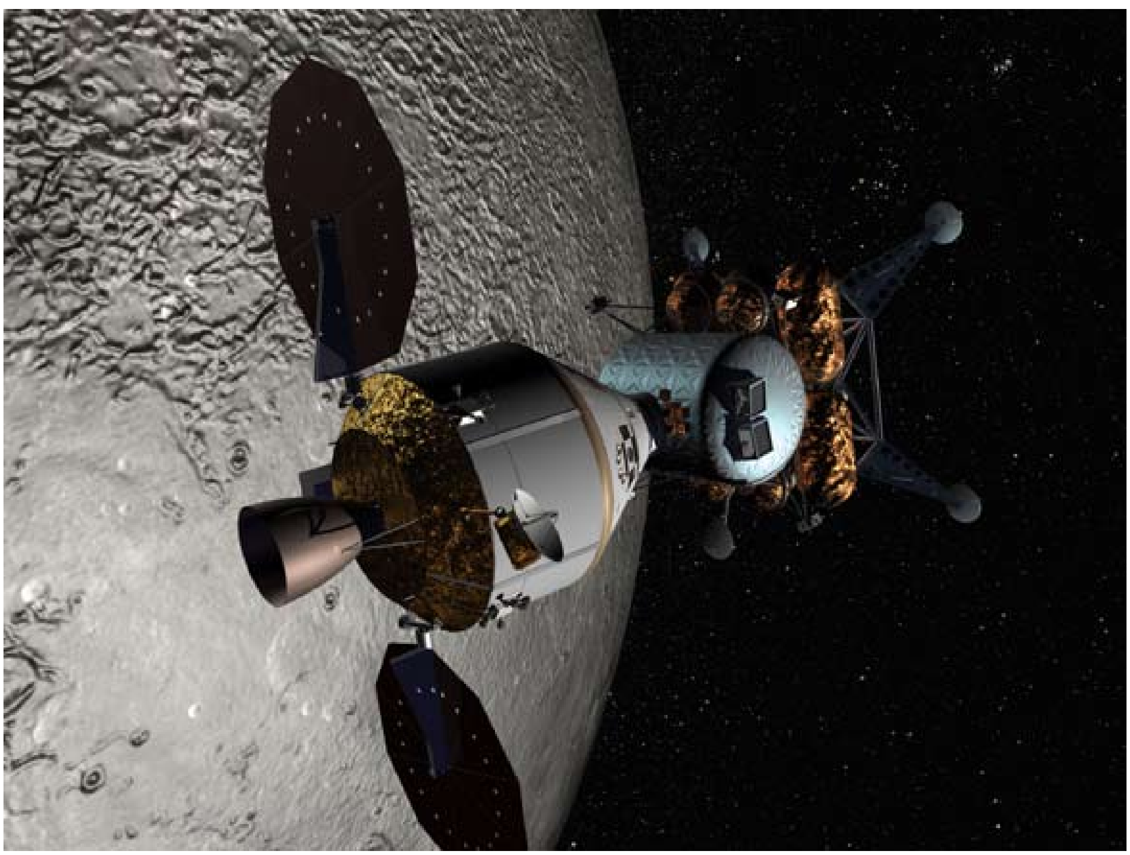
S.17 **Telemedicine:** Remote medical treatment of humans while they are in space. Telemedicine and remote surgery businesses have a large terrestrial market to provide leverage for Lunar services. Partnerships with companies such as Keosys Medical Imaging, TMA-Medical, Cisco Systems, Inc. and Ethicon Endo-Surgery will assist with creating a strong business plan. Other opportunities include mental health services, particularly for long-duration and international exploration, and the management of medical equipment accreditation and procurement.

S.18 **Medical equipment supply:** Physical medical supplies for treatment of humans in space, including for use in space-specific treatment methods.

Lunar Access

Moderators:
Chris Boshuizen
Zahra Khan
Matt Lacey

Working Group:
Julie Bellerose   Aisha Bowe   Christian Carpenter
A. C. Charania   Kevin Clinton   Matt Daniels
Laurie Darling   Jacques Dolan   Jonathan Goff
Jonathan Hofeller   Adam London   Michael Schoen



Background and Scope

Lunar access is a key element to commercial development of the Moon. Many missions have been sent to the Moon already, involving different types of trajectories and techniques, with evolving and improved guidance, navigation, and control (GNC) systems from year to year; for example, the Apollo missions, Clementine (NASA), Smart-1 (European Space Agency (ESA)), Selene (JAXA)), and many others. Apollo 8 and later missions also demonstrated landing capabilities as well as Lunar rover technologies. In terms of improving autonomous systems, the Soyuz, Progress, all-terrain vehicle (ATV), and hypersonic test vehicle (HTV) are examples of systems currently using autonomous rendezvous.

To this date, a few industries have looked at possible commercialization of segments involved in Lunar access, including the commercial development of the systems, vehicles, and services required to transport crew and cargo from the Earth to the Moon and all points in between. Companies in Europe and Russia have begun to explore these scenarios, but the United States has largely remained reliant on government sources. Recently companies such as Space-X, Rockeplane Kistler, and others have begun to look at the launch segment, but many other opportunities remain. Orbital showed the challenges involved in on-orbit docking with the Dynamic Analysis Research Tool (DART) mission. Among current studies, Space System/Loral is now advertising a Space Tug to use in space for servicing between spacecraft. The Defense Advanced Research Projects Agency (DARPA) grand challenge plays an important role by providing demonstration mission competition such as autonomous docking demonstrated by Orbital Express from Boeing in 2007.

Near Term Lunar Access Markets

Following is a list of near-term commercial opportunities as identified by the Lunar Access working group. The full list of near-term (less than 10 years), mid-term (10-20 years), and far-term (20 years plus) opportunities from each group can be found in the Appendix A time-phase analysis table. Appendix B has a market analysis for each near-term opportunity, and Appendix C has identified risks for each. Additional discussion and details are provided below for the items identified as special areas of imminent focus. Bolded phrases in the text indicate the near-term opportunities as listed in the Appendices B and C, for reference.

Landers

A.1 **Small Lunar landers:** Small landers could provide the capability to soft-land up to 100 kg on the Lunar surface, departing from low Lunar orbit (LLO). If such a capability existed today, NASA, Google X Prize teams, university, and other users would be able to place payloads (on the Lunar surface) for science or other applications. Many players are working in this area, such as NASA Ames Research Center and Google X Prize teams. Further cost and mass reductions in GNC, power, and propulsion technologies would increase the capability of these systems or reduce their costs, improving the business case for their development.

Technology enablers for small Lunar landers include the development of small-scale, high-thrust/-weight propulsion; off-the-shelf GNC components, high performance-to-mass ratio power (solar + batteries), and nontoxic propellants. Design-oriented enablers include first-lot purchase guarantee, modular and well-defined interfaces, modular subsystems/components, and other non-rocket deceleration systems.

A.2 **Multiple-lander U.S. EELV Secondary Payload Adapter "ESPA ring":** This ring would allow small landers to piggyback on other landers being launched, and provide a way for landers to be deployed at various intervals across the Lunar surface. Modular design and well-defined interfaces would be near-term opportunities, particularly for companies with previous docking/satellite adapter experience. Partnership opportunities would be great between satellite, lander, and other spacecraft companies and institutions.

Secondary Payloads

A.3 **Secondary payload ETO launch vehicle adapters:** Using secondary payload adapters for existing launch vehicles as the basis of future spacecraft would enable more launch opportunities, potentially at a lower cost. For example, the ESPA ring can be used to accommodate multiple small spacecraft (six 400-kg spacecraft for the initial standard ESPA ring). There are also international efforts (such as the Ariane Structure for Auxiliary Payloads (ASAP) ring for the Ariane 5, with eight 120-kg spacecraft). NASA could also institute a testbed program where NASA would purchase secondary payload rings as a standard part of its launch vehicle purchase. These launch opportunities would then be given to government, industry, or academia on a down-select basis as part of overall outreach of the main spacecraft on the launch vehicle. These could be used as orbital testbed opportunities, enabled via modular design, manufacturable, and having few configurations. Baseline prices (without major enhancements to the baseline ESPA ring) are envisioned to be around US$1–2M.

Unmanned Space Tug

A.4 **Unmanned space tug demo mission:** The spacecraft tug would be a spacecraft that rendezvous with a customer spacecraft and transports it to another spacecraft or destination within the same orbit (small total delta V, not orbit transfers). For example, the tug could bring space junk to an orbital dumpster. This technology would provide simplified and possibly standardized rendezvous procedures, which could allow mass/cost/complexity savings on the customer spacecraft, simplification of assembly in space, and standardized cargo and resource delivery. The tug technology should be very versatile and scalable so that it could be applied in as many uses as possible. The technology could also be enabled by a government-funded demonstration mission, community acceptance, and technologies such as rendezvous and docking technology (hardware, GNC), fuel-tank refilling, and spacecraft autonomy. Existing case studies include studies for ESMD (Orbital, Andrews, Aerojet), university research, limited demo missions (Disaster Assistance and Rescue Team, Orbital Express), and a study by General Electric.

Unmanned Space Ferry

A.5 **Unmanned space ferry demo mission:** A spacecraft ferry would rendezvous with a customer spacecraft and transport the customer spacecraft to a new orbit. The ferry spacecraft would be reusable and multimission applicable. A spacecraft ferry would present opportunities to deliver more usable mass to orbit or lower the cost of launching a fixed payload, move spacecraft between orbits, extend spacecraft orbit lifetime, and provide orbital disposal services. A ferry could offer services from and to anywhere between LEO and LLO, including:

» LEO to geosynchronous Earth orbit (GEO)

- LEO to geosynchronous transfer orbit (GTO)
- LEO to LLO or Lunar Lagrange points
- Between neighboring orbits
- LEO to medium Earth orbit (MEO)
- LLO to Earth or Lunar Lagrange points

The delta V required for a ferry that performs transfers from LEO to LLO to LEO is similar to a one-way Mars mission, so the same spacecraft designed for Lunar or communications satellite applications could also be used for single (or with trip-time allowances, multiple) Mars missions.

Automated Rendezvous and Docking

A.6 **Automated rendezvous and docking demo on-orbit:** Traditional Lunar missions are phased around the LEO-to-LLO-to-Lunar surface transportation segments. Multiple manufacturers will likely create a variety of systems to either land on or carry payloads to Lunar orbit or the Lunar surface. For an open Lunar architecture to exist, a standardized yet flexible docking system will be required to enable interoperability between this wide array of vehicles. A private company could take two different approaches to provide this hardware:

Design and develop an all-inclusive Research and Development (R&D) package

- Mechanical/electrical docking interface (both active and passive parts)
- Space-to-space command and control system
- Rendezvous and proximity operations sensors (multiple sensor packages)
- Robotic arm
- Payload/cargo transfer
- Refueling
- Power and data transfer
- Grapple assist for docking

Design and develop an adjustable-diameter mating adapter

- The adapter should accommodate vehicles/cargo that have different-size docking interfaces to increase flexibility in vehicle design and enable open Lunar architecture.

Where several companies that have core competencies in each of the AR&D subsystems—hardware, sensors, and communications—exist, no companies offer full human-rated, configurable AR&D systems for the commercial mass market. Currently employed human-rated technologies are based primarily upon Russian hardware, presenting several dependency and ITAR concerns. Furthermore, these technologies have limited application for smaller spacecraft and satellites. The market lacks a singular approach to a full range of AR&D spacecraft to enable straightforward cargo/propellant transfer or vehicle relocation.

Current non-automated systems require intensive human-in-the-loop involvement with limited accuracy. New systems would improve the accuracy and flexibility of spacecraft design. A company could sell these systems to both the payload and the transfer vehicles. Technology enablers include configurable docking mechanism technology, an open Lunar architecture, and a thriving commercial space market.

Access Services

A.7 **Commercial orbital test services:** A standard orbital bus can serve as a testbed for new technologies to promote them from technology readiness level (TRL) 5–6 to TRL 8–9 for incorporation into operational missions. The bus should have standard interfaces for box-level or subsystem-level payloads. The payloads should meet a standard set of mass and power characteristics. Launches should occur on a regular basis (at least annually) with physical integration of specific payloads within two months of launch or less, to enable launch of the payloads that are ready to go without delaying for ones that are not. From the perspective of the payloads, this scenario enables a definite launch date and an ability to delay to the next launch if they meet schedule problems. In general, this program could be an offshoot of the NASA Commercial Off-the-Shelf (COTS) Program, with complementary functions of the New Millennium Program. Technology enablers include picking from a large pool of possible technologies, having standard interfaces between the payloads and the orbital testbed, standardizing launch and orbital environments and payload mass parameters, having additional computing power for analysis while still on the ground to advance, and doing a cost-benefit analysis of additional testing versus incorporation into an operational mission.

Orbital Propellant Depots

A.8 Orbital propellant depot **demo mission:** Propellant depots are facilities for storing and aggregating propellants (cryogenic and storable) and then transferring them to end users such as reusable Lunar transfer vehicles/ferries. This ability is fundamental to the development of an affordable, reusable cis-Lunar transportation industry.

Propellant depots (and associated transfer/storage services) allow large-scale commercial transportation using existing Earth-to-orbit launch systems. They also allow in-space transportation systems to immediately benefit from technology improvements in low-cost Earth orbit access (high-flight-rate reusable launch vehicles (RLVs), etc). For instance, while existing launch systems might allow for propellants to be sold on orbit for $10,000, future technologies could allow propellants to be sold profitably for much less. These technologies and services allow for a safer and more robust transportation architecture that can be organically grown as cis-Lunar transportation markets grow. A future electromagnetic launcher 1 (EML1) or EML2 depot could allow commercial transportation to extend to the Lunar surface (servicing NASA or other international bases, commercial mining ventures, Lunar surface tourism, etc).

Propellant depots also help Lunar ISRU projects more easily close their business cases. Without the ability to store and transfer propellants on orbit, ISRU is limited in application to refueling only on the Lunar surface. With LEO and eventually Earth-Moon-Lagrange point depots, there is a ready and much larger market for Lunar ISRU than if such services did not already exist.

References

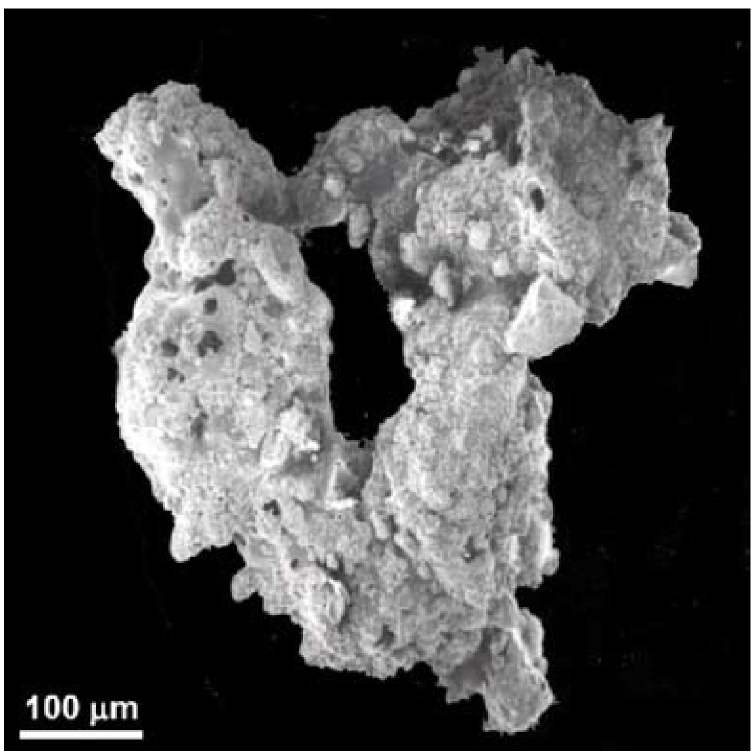
http://piezohydraulics.com/brochure/pdfs/CSAEngineering_ESPA.pdf
http://www.kirtland.af.mil/shared/media/document/AFD-070404-096.pdf
http://www.aeroastro.com/publications/SSC03-II-7.pdf
http://www.aeroastro.com/spacecraft/espa

http://centaur.sstl.co.uk/SSHP/launcher/launch_asap.html
http://www.arianespace.com/site/documents/ariane5_asap_index.html
http://www.arianespace.com/site/images/ASAP5-manual.pdf
Final report for In-Step 2573
NASA CR-78680
AIAA-2006-4435
IEPC-2005-320
Settled Cryo Transfer papers, ULA
http://unitedlaunchalliance.com/docs/publications/Atlas/Centaur_In-Space...
http://www.popularmechanics.com/science/air_space/4224660.html
http://spaceflightsystems.grc.nasa.gov/Advanced/Capabilities/CryoFluid/
http://piezohydraulics.com/brochure/pdfs/CSAEngineering_ESPA.pdf
http://www.kirtland.af.mil/shared/media/document/AFD-070404-096.pdf
http://www.aeroastro.com/publications/SSC03-II-7.pdf
http://www.aeroastro.com/spacecraft/espa
http://centaur.sstl.co.uk/SSHP/launcher/launch_asap.html
http://www.arianespace.com/site/documents/ariane5_asap_index.html
http://www.arianespace.com/site/images/ASAP5-manual.pdf

Lunar Environment Utilization

Moderators:
Melissa Battler
John Karcz
Sanjoy Som

Working Group:
Trinity Allen Alex Baklashov Gwen Barnes
Dai Dinh Trevor Foster Ryan L. Kobrick
Marianne Mader Jessica Marquez Sean Mobilia
Joseph E. Palaia Erin Tranfield Andrew Turner
Mary Beth Wilhelm



A lunar dust grain. Image courtesy of NASA.

Background and Scope

ISRU has a long history of research, particularly following the return of Lunar regolith brought back to Earth by Apollo astronauts. Specifically, the extraction of oxygen from the regolith has been the subject of much focus, particularly in the last two decades (e.g., Allen et al. 1996; see also ISU 2006 and references therein). Igneous silicate minerals (e.g., plagioclase feldspar and olivine) and iron-titanium oxides (e.g., ilmenite) can be reduced to extract other useful elements; in particular, the reduction of ilmenite with hydrogen produces iron and water, among other things. While the presence of hydrogen is rare on the Moon (implanted, along with helium, by the solar wind), innovative methods have been proposed to extract it from the regolith (e.g., White and Hirsch, 1985). The use of reduced carbon originating, for instance from the decay of human-produced organic matter, could potentially be used to reduce anorthite. Processes such as carbothermal reduction and pyrolisis are promising techniques to extract volatiles from the rock. Volatiles are only one of the multiple useful substances extracted from the Lunar regolith. Metals such as iron and titanium can also be extracted. Finally, the physical properties of the Lunar regolith, its abrasiveness, and its natural protection against solar irradiation can be addressed with entrepreneurial twists.

The Lunar environment offers multiple opportunities for resource utilization. While the scientific merits of such use are worthy on their own, successful, realistic exploitation will depend significantly on commercially viable enterprises. This section identifies entrepreneurial opportunities using the Lunar environment in the near term (defined as the time from now until human landing), the midterm (from Moon landing until 5 years after), and the far term.

Near Term Lunar Environment Utilization Markets

Following is a list of near-term commercial opportunities as identified by the Lunar Environment Utlization working group. The full list of near-term (less than 10 years), mid-term (10-20 years), and far-term (20 years plus) opportunities from each group can be found in the Appendix A time-phase analysis table. Appendix B has a market analysis for each near-term opportunity, and Appendix C has identified risks for each. Additional discussion and details are provided below for the items identified as special areas of imminent focus. Bolded phrases in the text indicate the near-term opportunities as listed in the Appendices B and C, for reference.

Cartography

E.1 **Lunar map production:** Synthesis of maps showing different Lunar characteristics (elevation, thermal inertia, mineralogy…), with simple tools to access, distribute, and use this data. In the near future (before humans return to the Moon), the primary form of “products” or “returns” from the Moon will be in the form of data and imagery that are sent back from orbiters and landers. An entrepreneurial opportunity identified to capitalize on this vast amount of information would be to synthesize, organize, and interpret these data into a product accessible to a very broad audience. More specifically, this commercial venture would provide a software interface based on the model of Google Earth. The “basic version” would be available for free to everyone, while the “advanced version” would be available to interested parties as commercial licenses (in the model of Google Earth Pro). All maps would be selenoreferenced, and would include, for instance, elevation, thermal inertia, visible, albedo, mineral location, and slope maps.

In addition to those maps, data-extraction capabilities would be included (for a fee), that would allow for easy and direct import into very powerful geographic-information-system (GIS) software suites, such as those proposed by Environment Systems Research Institute, Inc. (e.g., ArcGIS) or ITT Visual Information Solutions (e.g., Extracting Information from Geospatial Imagery (ENVI)). The objective of this commercial opportunity thus goes beyond simply integrating all the data, also allowing simplified means of distributing it.

Currently, there is a lack of "Lunar mapping experts" who can provide "added-value" products focused on the Lunar surface. This service will be a key service that agency and commercial missions will need to help in mission planning and design. Even if a "return to the Moon" is unsuccessful, Lunar mapping services could be valuable for scientific and educational/outreach purposes.

Tools and Equipment

E.2 **Ruggedized instrumentation, tools, and equipment:** Miniaturized and more robust field equipment for exploration programs (mining, astrobiology, deep sea) in remote and harsh environments. As resources on Earth become scarcer, mining and oil/gas companies are now conducting exploration programs in more remote areas (e.g., Arctic regions, deep-sea areas, etc.). Those areas are particularly interesting for Astrobiology as well. A relativity new area of expertise is the terrestrial application of miniature, ruggedized equipment that can be used directly in the field. The advantages of such instrumentation include the savings in transportation costs to access remote areas and the ability to obtain results immediately without waiting for post-field analysis. These factors are critical for areas that are difficult to access and where return time may be long between exploration trips (e.g., short summer field seasons in the Arctic).

This development of miniaturized, ruggedized field instruments has a direct application to near- and far-term exploration of the Moon (through lander, rover, as well as human missions). A key entrepreneurial activity would be to recognize this specialization and expertise in terrestrial mineral/oil and gas exploration and to invest in key technologies that would later be used to benefit Lunar exploration.

Instead of getting space experts to become geological experts, we (the space industry) could approach the terrestrial experts and allow them to extrapolate their technology to also include a space application.

Regolith

E.3 **Sale of Lunar dust:** Commercialization of Lunar dust as a novelty item (using Atomic Force Microscopy to engrave a wide range of messages on dust grains and then sell large, framed scanning electron micrograph (SEM) micrographs of message in addition to the dust itself). The Apollo landings focused humanity's interest on the Moon, and as we prepare to return to the Moon that interest will return. Imagine if you could own just a small sample of Lunar dust, or even better, imagine if you could own a beautiful image of Lunar dust that has been engraved with your personal message.

A business could be centered on the sale of Lunar dust. The dust could be sold as either a small 0.5-g sample in an ampule or as a single grain. The single-grain sample could have a message of the consumer's choice engraved on the surface using Atomic Force Microscopy technology. Consumers would be unable to see their message, of course, so the Lunar dust grain could be imaged with a Scanning Electron Microscope (SEM). The final product would be a large framed SEM micrograph of the engraved Lunar dust grain and the Lunar dust grain itself preserved in a way that the customer wants, i.e. a ring, an ampule for a necklace, etc. The requirement of only a small amount of Lunar sample for a large number of samples that could be sold to consumers makes this idea more viable.

There is currently no Lunar dust on Earth that can be used for this purpose. The Apollo era Lunar dust samples are far too precious and will not be released from the JSC Lunar Dust Curation Facility for such use. Execution of this entrepreneurial opportunity would require a fairly large amount of Lunar soil, which could be piggybacked on a Lunar return mission. The endeavor could possibly work with an existing mission, rewarding returns of Lunar dust to Earth.

E.4 **Dust-mitigation techniques**

E.5 **Terrestrial bioremediation techniques (medicine)**

References

Allen, C.C, Morris, R. V., and McKay D. S. (1996): "Oxygen extraction from lunar soils and pyroclastic glass". Journal of Geophysical Research, 101, 26085-26095.
Blair, B.R., Diaz, J., Duke, M.B. (2002):" Space Resource Economic Analysis Toolkit: The Case for Commercial Lunar Ice Mining". Final Report to the NASA Exploration Team. CSM/JPL/CSPCSM/JPL/CSP. SRD Case 1.0 - 01/08/03. Available Online. Accessed 14 Feb. 2008. URL: http://www.isruinfo.com//docs/LDEM_Draft4-updated.pdf

ISU (2006): "Fertile Moon, Final Report". International Space University, Strasbourg, France.

Kokh, P. (1995): "Commercial Moonbase Brainstorming Workshop". Workshop on the "Design Requirements for a Commercial Moon Base", Science/Science Fiction Convention in Milwaukee. Available Online. Accessed 14 Feb. 2008. URL: http://www.lunar-reclamation.org/papers/commercial_moonbase_wrksh.htm

Landis, G.A. (2002): "Technology for solar array production on the Moon". IEEE Photovoltaic Specialists Conference. (LOCATION)

Landis, G.A. (2007): "Materials refining on the Moon". Acta Astronautica, Vol. 60, Issues 10-11.
Schmitt, H.H. (2004): "Lecture 10: Potential Resources of the Moon". Resources from Space (Course NEEP 533), Fusion Technology Institute, University of Wisconsin-Madison. Available Online. Accessed 14 Feb. 2008. URL: http://fti.neep.wisc.edu/neep533/SPRING2004/neep533.html

White D, and Hirch, P. (1985): "Microbial extraction of hydrogen from the lunar dust". Lunar Base and Space Activities Meeting.

Cultural Industries

Moderators:
Karen Lau
Rocky Persaud

Working Group:
Chisato Kobayashi Tim Bailey Randall Echevarria
Michael Lamberty Greg Mindorff Talmon Firestone
Karyl Newman Cassie Kloberdanz Laura Burns
Stephen Jeffress Patrick Mellody Susan Fonseca-Klein
Bruce Klein

Background and Scope

This group examined and identified entrepreneurial activities that inspire interaction among people, societies, and technology as we move off the planet towards the Moon and beyond. Extending human civilization to other terrestrial worlds, including the Moon, will see the birth of cultural industries unique to both the Moon and extensions of Earth culture. A new paradigm will be created in the fusion of technology prowess, social adaptation, and evolving expectations.

The working group discussed the following categories of cultural industries: entertainment, tourism, fashion/design/arts/music, and information/news/media. Aiding commercial activity in these cultural industries would be helpful for fulfilling NASA's education and outreach initiates, and would have a cultural impact that is necessary for expanding the global economy to the solar system. NASA can sell the importance of considering future Lunar cultural industries on the basis of education and outreach.

Near Term Cultural Industries Markets

Following is a list of near-term commercial opportunities as identified by the Cultural Industries working group. The full list of near-term (less than 10 years), mid-term (10-20 years), and far-term (20 years plus) opportunities from each group can be found in the Appendix A time-phase analysis table. Appendix B has a market analysis for each near-term opportunity, and Appendix C has identified risks for each. Additional discussion and details are provided below for the items identified as special areas of imminent focus. Bolded phrases in the text indicate the near-term opportunities as listed in the Appendices B and C, for reference.

Immersive Experiences

The Superhero Experience

C.1 **Parabolic flight agreements:** Comic books and superheroes have been around since the 1930s. A first of its kind, The Superhero Experience would allow people of all ages to recreate the abilities of their favorite action hero... all in reduced-gravity conditions beginning with parabolic flight. Potentially available in the next five years, this business concept could eventually be translated to the Lunar surface. It will take advantage of the Moon's 1/6th gravity to give ordinary humans the opportunity to experience the extraordinary. Experiences could include flying like Superman, swinging from Spiderman's web, or lifting a replica car like the Incredible Hulk.

Partnerships can also form with existing media outlets and personalities. One example is Stan Lee's "Who Wants to Be a Superhero?" reality television show. Introduction of The Superhero Experience concept could come through partnership with the existing program. The show could have a challenge where the heroes have to perform a task while flying in a parabolic flight. This type of show would probably have a huge following in Japan, where Manga has a nationwide following.

Remote-controlled Rovers

C.2 **Remote-controlled rovers in extreme locations on Earth and on the Moon**

Robotic Video Games:

C.3 **Self-contained battlerooms to control robots:** Self-contained battlerooms could be created to allow players to control robots remotely with a story line (real/virtual) in LEO.

High-definition Sensory Media Experiences:

C.4 **Refine existing experiential devices such as force-feedback, 3-D goggles, and pressure-sensitive clothing.** Use rovers to gather data from remote site for users to experience with virtual reality technology.

Lunar Skate Park

C.5 **Space-themed sports parks** with space-themed products, boards, and U-ramps. Terrestrial space-themed sports parks could lead to sporting events in reduced gravity and microgravity in the future.

Space Honeymoons/Weddings

C.6 Space-themed **wedding ceremonies and honeymoons** in space.

Reality Television/ Game Shows

Reality Game Shows

C.7 Tuff'Nuff'forSpace Earth-based **reality game shows:** A space game show could ask, "Are you tough enough for space?" Competitors would have to endure astronaut training with physical and mental challenges. Competition and consequences are always popular for engaging an audience in an event. Space-themed TV shows have been extremely popular (Star Trek, Lost in Space, Marvin the Martian, Mork and Mindy, Babylon 5, Stargate, etc.). The reality show "Space Cadets" filmed and aired in the UK in 2005. The 10-episode show was built around an elaborate hoax, where 10 people believed they were training and actually going into space. Several other space-themed reality shows have been promoted, though none has yet been produced. Possible challenges to a space-themed reality show follow:

The experiences used for training astronauts and cosmonauts are not typically used in competitive scenarios and may not be capable of supporting multiple participants in a short time period. This problem would increase the cost of the overall production by extending the amount of filming time required.

The unique facilities and small number of options could lead to high costs for using the training equipment.

Some of the training is inherently dangerous and may present legal roadblocks or require a high level of risk acceptance.

Training facilities may be difficult to access because of government regulations or limited time between primary spaceflight participant training (they may already be at maximum capacity training astronauts or cosmonauts).

The training experiences may need to have "competitive" criteria added to the typical "do it until you get it right every time" training scenario.

Space Lottery:

C.8 Parabolic and suborbital **flights as prizes for a lottery** giving a space tourism experience.

Space Products

Books

C. 9 **Guidebook for the Moon:** Written for a theoretical tourist, Lonely Moon would be based on the "Lonely Planet" series of guidebooks. Lonely Moon would offer travel advice, detailed maps, travel news, popular message boards, and health information related to a trip to the Lunar surface. It would be available in both the virtual and real worlds. As travel to the Moon becomes more frequent, the series could be expanded to include chapters or additional volumes on specific Lunar destination sites or other tourist locations, including Mars and space stations. Tours could also be conducted by automated transport that informs the passengers of interesting locales as they reach them. Using future holographic display technologies, the guide could be made interactive and multidimensional. An online discussion forum already exists, so an interactive community for Lunar destinations could follow.

Space Jewelry

C.10 Jewelry **using Lunar rocks or dust, meteorites, crystals, etc.:** Use materials from space in jewelry. Synthetic jewelry is a new market opportunity, and examples include gem-quality synthetic diamonds entering the jewelry market in recent years. The technology used to create them is improving rapidly. The environment of space could be used to create unique jewelry. Microgravity crystal growth chambers could be used to harvest synthetic gemstones for crafting into jewelry on Earth. In the longer term, Lunar rocks could be used in jewelry. Initial customers might be space tourists and art/jewelry collectors; this market is clearly a niche market for the frontier phase of Lunar development. A large mass-market for microgravity-created synthetic jewelry and Lunar-rock based objects d'art could emerge. Gem-quality crystals should be easier to grow in microgravity, but getting there is the challenge. The technology for the growth chamber would need to be developed, and a provider of orbital rendezvous would be necessary to retrieve them.

Lunar Data Archiving

C.11 **Collecting materials for Lunar archiving:** Pictures and other data could be stored on the Moon in a readable format. Others have proposed archiving of data for public or corporate purposes. For example, a 2007 International Space University (ISU) project called "Phoenix" focused on archiving genetic and technical information on the Moon that could be accessed remotely to aid in recovery from a major Earth-bound catastrophe. Turner and Erikson also considered using the Moon as a remote, physically secure location for businesses to back up critical electronic data. This proposal is distinct in that it would be aimed at (and within the price range of) private individuals who wish to preserve personally meaningful data.

A Lunar archive of analog images and text could be created on stable physical media, such as thin glass plates or metal foil. Private individuals could preserve memorials and other personally meaningful data (i.e., wedding photos) by "sending them to the Moon forever." If the mass of the media is kept low, the cost per page would be within the reach of individuals. For example, assuming a cost of $150,000 per kg delivered to the Moon, the cost of delivering a one-gram "page" would be $150. (A sheet of gold foil 10-cm square and 5 microns thick has a mass of approximately 1 gram.)

The media could be preserved intact for at least hundreds or thousands of years. The archive could be completely passive and inert once delivered, because no power is required, temperature requirements are not stringent, etc. As an option, onboard cameras could be included to document that the archived materials indeed arrived on the Moon (i.e., by sending back digital photographs of the media with a moonscape in the background). This, of course, would increase the complexity of the archive, and add greater requirements in terms of power, etc.

Because data storage is visual—images and text etched into metal or glass—there are no concerns that it will become unintelligible because of changes in computer technology, etc. At most, magnification might be required to recover images and text (assuming it might be reduced in size to reduce the number of pages required).

Video Documenting

C.12 Professional editing and documentation of terrestrial space travel experience creating **commemorative videos.** Professionally filed and edited videos could document various terrestrial space travel experiences such as space training, zero-gravity, or space adventures experiences.

Space Luggage

C.13 Very lightweight **space-themed luggage** could be crafted using space materials.

Arts & Entertainment

Cirque de Lune (terrestrial performances)

C.14 Partner with a troupe such as Cirque du Soliel to create a space-themed acrobatic show. Encourage collaboration with NASA and Cirque du Soleil in producing a Lunar-themed resident show that could run at a tourist-heavy NASA center such as the Kennedy Space Center (KSC). Cirque is very successful, and there is little doubt that any show they produce will do very well. The company has no significant competitors, and its brand name/image has grown to become golden. The very strong brand awareness of NASA would most likely be seen as an opportunity or an advantage to Cirque in marketing such a show. An example show idea could find a young man and woman moving to the Moon as part of a future permanent facility. Each act would reflect various emotional experiences that each player goes through, and/or each act could create artistic and thematic depictions of emergency situations or mission successes. The show would culminate in the couple’s falling in love through their shared experiences at the facility. Cirque is already masterful at defying gravity, so would be very well suited to depicting low-gravity artistic expressions. Trampoline routines, tumbling routines, song, dance, acrobalance, “moon boot” dance/acrobatic routines, etc. could all be part of the show.

Spacecraft Art Studio

C.15 An arts studio could feature **art with discarded space vehicles and materials.** Art could be displayed on spacecraft, aircraft, airports, spaceports, traditional art venues, and space events.

Lunar Arts Endowment Program

C.16 A **Lunar Arts Endowment** could be developed to fund the arts. An “Artist in Space” program similar to the “Teachers in Space” program could be created.

Space Fashion Shows

C.17 **Terrestrial showcases of space-themed fashion** design could be developed.

Outreach

Professional Groups

C.18 **Technical and media public relations teams:** A public affairs agency could specialize in the space-related industry. This opportunity would begin with the formation of a public relations agency that focuses entirely on the commercial spaceflight industry. Starting immediately, this opportunity would have NASA as a primary customer, and as other companies move forward in their development they would be able to employ the agency for their public and media relations needs. It is imperative that our incredible new Lunar businesses reach the public, and for that a space public relations agency is proposed. Beyond the typical function of public relations professionals, this organization would employ well-respected journalists to profile space-related achievements. Serving as a space-themed associated press, their stories would be published in major mainstream media. Their primary goal would be to show the diversity of space endeavors and to substitute actual faces for NASA's sterile image. The focus would expand to include those involved in Lunar exploration, Lunar entrepreneurship, and other contributions to our country's future in space.

Education

C.19 Specialize in creating **educational materials** in many languages, especially for those with special needs, and make available to parents public and private schools.

References

http://en.wikipedia.org/wiki/Space_Cadets

http://www.hobbyspace.com/Tourism/#OrbitalGames

Anderson, Eric: The Space Tourist's Handbook: Where to Go, What to See, and How to Prepare for the Ride of Your Life

"Phoenix" - A team project (SSP 07) by the International Space University into archiving data against Earth-bound catastrophes.

Turner, Andrew E.; and Erikson, Ray: Use of the Moon for Off-Site Data Storage and other Telecommunications Applications. AIAA 2004-3221.

Appendix
Next Generation Exploration Conference-2

Appendix A

Infrastructure, Utilities, and Consumables Working Group Time-Phase Analysis			
	Near Term t < 10 years	Mid-term 10 < t < 20 years	Far-term 20 < t < 30 years
TRANSPORTATION			
Autonomous robots/rovers	I.1 Terrestrial rover sandboxes	High-speed locomotion	None
	I.2 Exploration rovers	ISRU (mining) rovers	Human collaboration
	I.3 Tele-operated repair robots	Construction rovers	None
Mobile platforms	I.4 Small-scale people, cargo movement capability	Larger-scale movement capability, lunar trucking	Lunar train/flying platforms
Surveying and road development	I.5 Surface topography mapping	Basic route identification and mapping, outpost site identification and preparation	Road clearing, road paving, site survey and preparation for settlement construction
Fuel Depots	I.6 Development of fuel depot systems	Maximize crew/cargo on launch, fuel up in LEO	Moon orbit depots w/earth-derived fuels
			Moon orbit and surface depots w/lunar-derived fuels
Orbital Hab/Xfer Station	I.7 Orbital hotels in LEO	Orbital transfer stations in LEO	Orbital transfer stations in LMO
			Lunar surface hotels
Power Recharge Station	I.8 Electric car stations	Local stations	Full network
	I.9 Stations for dedicated network of terrestrial rovers	Primary path way-points, roving power supplies	None
Launch/Landing Facilities	I.10 Terrestrial launch/ landing facilities	Basic site preparation for lunar landing sites (marking, clearing, some leveling)	Established lunar space ports
HABITABILITY			
Design	I.11 Human factors	Trans-hab integration, design firms	One unified infrastructure, full scale habitat production
Food	I.12 Food grown in habitat	Greenhouses	Agricultural systems
Logistics	I.13 Storage/cargo systems	Packaging/ shipping/ storage	None
Chemical Consumables (Oxygen, Hydrogen, Sulfur, Nitrogen, Carbon, etc.)	I.14 Delivery from Earth, distribution, and storage of chemical consumables	From lunar utilization, closed loop focus	From lunar utilization, growth accommodation
Water Infrastructure	I.15 Delivery from Earth, distribution, and storage of water	Water extraction from lunar environment, plumbing infrastructure between modular facilities	Urban infrastructure (water works)
Air Systems	I.16 Air systems (composition & pressure): ionic membrane, CO2 control systems, mechanical filtering of dust	CO2 scrubber, plumbing infrastructure between modular facilities	None
Waste Management	I.17 Piping, plumbing, external/internal recycling	None	Urban infrastructure

Space Suits	I.18 Breathing air, cooling, navigation systems, umbilical connections, crew survivability equipment	Full suit production	Advanced space suit lab habitats
Thermal Control Systems	I.19 Active/passive thermal control systems	None	None
General Equipment	I.20 Furniture, exercise, lab equipment, appliances, tools, supplies, clothing	None	None
POWER, COMMUNICATIONS AND NAVIGATION			
Power	I.21 Solar power generation/cryogenic storage	None	Nuclear
Communications	I.22 Private expansion of DSN	Communications relay satellites in orbit of the moon	Dedicated, high power, laser links between the Moon and the Earth
Navigation	I.23 Lunar navigation via high-resolution images and pattern-recognition advancements	Autonomous navigation algorithms that input DSN and mapping data.	Lunar GPS; augmented navigation intelligence software
FACILITIES			
Earth-based Research Facilities	I.24 Radiation testing facilities	None	None
	I.25 Thermal testing facilities		
	I.26 Microgravity testing facilities		
	I.27 Vacuum testing facilities		
	I.28 Dust testing facilities		
	I.29 Vibration testing facilities		
	I.30 Facility brokering		
Space/Lunar-Based Research	I.31 Orbital habitats	Utilizing the lunar environment, construction	None
	I.32 ISS centrifuge	Test facilities	None
Construction Materials	I.33 High S-W materials	None	None
	I.34 Memory shape materials	Intelligent materials	None
	I.35 Radiation protection materials	UV blocking materials (nanomaterials)	None
Construction Tools / Equipment	I.36 Lightweight tools	Intelligent Tools	None
	I.37 Simple construction rovers	Semi-autonomous machines	autonomous machines
Mining	I.38 Regolith excavation/mass-moving	None	None
	I.39 Sampling and drilling	Lightweight Mining	Self-cooled mining equipment
	I.40 Dry mining	Triangulation mining equipment (where to mine)	Drilling (for metals)
Data Storage	None	Shielded storage	Data/DNA/bio backup

Services Working Group Time-Phase Analysis

	Near Term t < 10 years	Mid-term 10 < t < 20 years	Far-term 20 < t < 30 years
Waste Management	S.1 Space-debris tracking and removal, vehicle recovery	Surface Debris tracking and removal, Disposable of consumables, fuel waste	Treatment of manufacturing waste, hazardous material effluent
	S.2 Removal and recycling of waste produced on the Moon		
Utilities Management	S.3 Multi-capability robotics, general services	None	None
Legal Advice	S.4 Legal advice for entrepreneurs	Legal Advice for astronauts	Enforcement
	S.5 Legal advice for legislators	Legal Advice for regulatory authorities	
Operational Support	S.6 Knowledge store on the Earth	Robotic Services	24-hour call center for emergency services, roadside recovery on the Moon
	S.7 Knowledge store on the Moon		
	S.8 Systems engineering and administrative documentation		
Industry Standards	S.9 Development and accreditation of industry standards	None	None
Communications	S.10 Data and services	Earth to Moon Atoms	None
Spectrum Management	S.11 Spectrum management and regulation	Bandwidth management and regulation	Local wireless network
Financial	S.12 Insurance	None	Banking on the Moon, Inventory trade, lunar stock exchange, Carbon credits
Space traffic management	S.13 Navigational signals	Routing and piloting	None
Cartographic Data	S.14 Cartographic Data	None	None
Agriculture	None	None	Production and supply of food
			Distribution of food
Education and Training	S.15 New recruit training	None	None
Health Services	S.16 Specialist treatment of astronauts, preventative medicine,	None	None
	S.17 Telemedicine		
	S.18 Medical equipment supply		

Lunar Access Working Group Time-Phase Analysis

	Near Term t < 10 years	Mid-term 10 < t < 20 years	Far-term 20 < t < 30 years
Landers	A.1 Small Lunar landers	None	None
	A.2 Multiple lander "ESPA Ring"	None	None

Secondary Payloads	A.3 Secondary payload ETO launch vehicle adapters	None	None
Unmanned Space Tug	A.4 Unmanned space tug demo mission	More complex functions, tasks, larger systems	None
Unmanned Space Ferry	A.5 Unmanned space ferry demo mission	Pre-deploy LSAMs, provide cargo delivery services to the moon and large GEO communication satellites.	None
Automated Rendezvous and Docking	A.6 Automated rendezvous and docking demo on-orbit	None	None
Access Services	A.7 Commercial orbital test services	None	None
Orbital Propellant Depots	A.8 Demo mission	None	None
Lunar Environment Utilization Working Group Time-Phase Analysis			
	Near Term t < 10 years	**Mid-term 10 < t < 20 years**	**Far-term 20 < t < 30 years**
Cartography	E.1 Lunar map production	Commercial space ventures (Google Lunar X-prize)	None
		Tourism	
		In-situ resource utilizations	
Tools and Equipment	E.2 Ruggedized instrumentation, tools, and equipment	None	None
Regolith	E.3 Sale of Lunar dust	Manufacture of products from bluk regolith for lunar architecture.	Resource extraction and production (Al, Si, Fe)
			Manufacture of bulk items.
	E.4 Dust mitigation techniques	None	None
Oxygen	None	Manufacture of oxygen-derived products for lunar use	Manufacture of oxygen-derived products for off-Moon use.
Power	None	Storage and sale of solar energy for the lunar infrastructure	Using the Moon for power storage.
Medicine	E.5 Terrestrial bioremediation techniques	None	None
Cultural Industries Working Group Time-Phase Analysis			
	Near Term t < 10 years	**Mid-term 10 < t < 20 years**	**Far-term 20 < t < 30 years**
IMMERSIVE EXPERIENCES			
Super Hero Experience	C.1 Parabolic flight agreements	Suborbital and orbital flights.	Superhero Experience Center on the Moon.
Remote Controlled Rovers on the Moon	C.2 Remote-controlled rovers in extreme locations on Earth and the Moon	Controlling RC rovers on the moon.	Custom user-designed rovers.
		Rover racing and competition.	
Robotic Video Games	C.3 Self-contained battlerooms to control robots	Extended robo-gameplay on the Moon.	Increased size and complexity of robo-gameplay.
High-definition Sensory Media Experiences	C.4 Refine existing experiential devices	Send HD sensory capture equipment on dedicated missions like lunar rovers	Stream HD experiences from lunar explorers back to Earth-bound viewers and from Earthly endeavours back up to Lunar colonists.

LunarSkate Park	C.5 Space-themed sports parks with space-themed products, boards, and U-ramps	Aerial Sports Competitions facilities in extreme environments (Antartica + Utah), in LEO, with live DJ's spinning	Orbital Athletic Competitions
Space Honey-moons/Weddings	C.6 Wedding ceremo-nies in space	Marriage authority in space.	Lunar-based "little white chapel."
REALITY TELEVION/ GAME SHOWS			
Reality Game Shows	C.7 Earth-based reality game shows ("Tuff-Nuff'for'Space")	Suborbital and orbital reality game shows.	Lunar-based reality game shows.
Space Lottery	C.8 Flights as prizes for a lottery	Lotto for orbital flights.	Lotto for orbital and lunar hotel/resort stays.
SPACE PRODUCTS			
Books	C.9 Guidebook for the Moon	Holographic or AI experiences.	Robotic lunar tour guides Lunar Geo-caching
Space Jewelry	C.10 Using lunar rocks or dust, meteorites, crystals, etc.	Easier harvesting of additional material.	Custom jewelry created on the Moon.
Lunar Data Archiving	C.11 Collection of materials. for lunar data archiving	First lunar archive.	Using lunar resources.
Video document-ing	C.12 Commemorative videos	Professional documentation of space experiences.	None
Space Luggage	C.13 Space-themed luggage	RC controlled luggage.	Lugguge adhering to spaceflight standards.
ARTS & ENTERTAINMENT			
Cirque De Lune	C.14 Terrestrial performances	Zero-G performances on para-bolic flights.	Lunar performances.
Spacecraft Art Studio	C.15 Art from discarded space vehicles and materials	Orbital studio on private space station.	Permanent lunar studio.
Lunar Arts Endowment Program	C.16 Lunar arts endowment	Sending artists to orbit or lunar habitats.	Orbiting art school. Lunar art school.
Space Fashion Shows	C.17 Terrestrial show-cases of space-themed fashion.	Testing fashions in orbital ve-hicles.	Producing fashions, holding shows, in microgravity or on the Moon.
OUTREACH			
Professional Groups	C.18 Technical and media public relations teams	Increased credibility and client list.	Lunar surface work.
Education	C.19 Education materials	Link schools worldwide with activi-ties in orbit so students can learn from teachers in space	Provide education for residents of lunar facility

Appendix B

Infrastructure, Utilities, and Consumables Working Group Market Analysis

Opportunity Code	Near-Term Commercial Possibility	U.S. Government (USG) Supply	USG Demand	Private (non-USG) Supply	Private (non-USG) Demand
TRANSPORTATION					
I.1	Terrestrial Rover Sandboxes	None	NASA (PAO/ Outreach), Department of Education	None (LunaCorp dissolved in 2003)	Tech companies - (historically RadioShack), commercial robotics companies
I.2	Exploration Rovers	MER, etc...	NASA, Department of Defense (DoD)	Google Lunar X PRIZE teams, iRobot's Packrobot	Google Lunar X PRIZE, international space agencies
I.3	Tele-operated Repair Robots	Robonaut, Orbital Express (DARPA)	NASA, DoD (satellites) Navy (underwater repair)	Statoil pipeline repair robot	Satellite owners, international space agencies, oil and gas
I.4	Small-scale People and Cargo Movement Capability	ATHLETE, MULE, Chariot	NASA, DoD	Moonbuggy (manned/unmanned vehicles used on Earth), RaceFab (robust vehicle frames)	Construction, medical, racing, railway industry
I.5	Surface Topography Mapping	NASA	NASA, DoD	Terrestrial surveying companies, Google, Mapquest, Rand McNally	Developers, mining companies, tourism companies
I.6	Development of Fuel Depot Systems	None	NASA Satellite operators	None	Satellite operators Lunar tourism
I.7	Orbital Hotels in LEO	ISS	NASA	Bigelow ILC Dover	Space tourism Universities
I.8	Electric Car Stations	None	None (transportation?)	EDF (United Kingdom)	Automakers (indirect), electric car owners
I.9	Stations for Dedicated Network of Terrestrial Rovers				
I.10	Terrestrial Launch and Landing Facilities	NASA, DoD facilities	NASA, DoD, NOAA, Department of Transportation (DoT)	Sea-Launch, Spaceport USA	Universities Companies
HABITABILITY					
I.11	Human Factors	None	Research facilities	Environmental consulting firms, design firms	None
I.12	Food Grown in Habitat	NASA	None	Hydroponics industry	None
I.13	Storage/Cargo Systems	None	DoD	None	Arctic/ remote expeditions
I.14	Delivery from Earth, Distribution, and Storage of Chemical Consumables	None	Laboratories	Chemical manufacturers	Laboratories, chemical manufacturers

I.15	Delivery from Earth, Distribution, and Storage of Water	NASA JSC	EPA, NASA, DoD	GE, Lenntech, etc.	Environmental/water reclamation advocacy groups; local communities
I.16	Air Systems	NASA JSC	NASA (ISS)	None	None
I.17	Waste Management	NASA JSC	EPA, NASA	Environmental consulting firms	None
I.18	Space Suits	NASA JSC	NASA	None	None
I.19	Thermal Control Systems	NASA JSC	None	None	Racing industry
I.20	Furniture, exercise, lab equipment, appliances, tools, supplies, clothing	NASA JSC	None	None	None
POWER, COMMUNICATIONS, AND NAVIGATION					
I.21	Solar Power Generation/ Cryogenic Storage	Deep Space Network TDRS satellites	Deep-space and Lunar missions - manned and unmanned	Other national space programs communications infrastructure	ESA, JAXA, ISRO, DLR, Google X Prize; other national space programs; potentially the Chinese and Russian space programs
I.22	Private Expansion of DSN	DSN	NOT IN TABLE	NOT IN TABLE	NOT IN TABLE
I.23	Lunar Navigation via High-Resolution Images and Pattern-Recognition Advancements	DSN, GPS	LEO, Lunar and deep-space missions	GLONASS, SETI, GALILEO	ESA, JAXA, ISRO, DLR, Google X Prize
FACILITIES					
I.24	Radiation Testing	Department of Energy (DoE), DoD, NASA	NASA, DoD, DoE	TRIUMF (Canada)	Universities and industry
I.25	Thermal Testing	DoE (Sandia, NREL, LBL), DoD (NRDEL, USNPS, TRTF), NASA	NASA, DoD, DoE	Gigabyte (Taiwan), Southern CA Edison, Power Electronics	Universities and industry
I.26	Microgravity Testing	NASA C-9	NASA, DoD	Zero-G, C-NES	Universities and industry
I.27	Vacuum Testing	NASA facilities	NASA, DoD, DoE	various	Universities and industry
I.28	Dust Testing	NASA facilities	NASA Cx	Universities, CSA	Universities and industry
I.29	Vibration Testing	NASA facilities	NASA, DoD	None	Universities and industry
I.30	Facility Brokering				
I.31	Orbital Habitats	NASA (ISS)	NASA, NSF, NIH	Private businesses could sell time on the ISS, Roskosmos, JAXA, ESA	Universities and businesses (medical, materials, chemical research)
I.32	ISS Centrifuge	None	NASA, NSF, NIH	Private businesses could sell time on the ISS centrifuge .	Universities and businesses
I.33	High Strength-to-Weight Materials	NASA, DoD	NASA, DoD	Chemical companies, universities	Airlines, chemical, research, etc.
I.34	Memory Shape Materials	NASA, DoD	NASA, DoD	Chemical companies, universities.	Airlines, chemical, research, etc.
I.35	Radiation Protection Materials				
I.36	Lightweight Tools	None	Any government agency that does construction	DeWalt, Bosch, other hand tools businesses	Tools for easier use for and people with reduced capabilities

I.37	Simple Construction Rovers	None	DoD	None	Mining, hostile environments
I.38	Regolith Excavation/ Mass-moving	None	None	Widely commercially available today	Compatible to Earth-based mining efforts
I.39	Sampling and Drilling	None	None	Widely commercially available today	Compatible to Earth-based mining efforts
I.40	Dry Mining	None	None	Widely commercially available today	Wide demand today

Services Working Group Time-Phase Analysis

	Near-term Commercial Possibility	US Govt (USG) Supply	USG Demand	Private (non-USG) Supply	Private (non-USG) Demand
S.1	Space Debris Tracking and Removal	NORAD (partially), ESA	Protection of existing space assets, including hardware and orbital slots	Tracking: Corona space, EOS, SCC Removal: Potential for development of tether technology, etc.	Commercial satellite operators
S.2	Removal and recycling of waste produced on the Moon				
S.3	Multicapability Robotics, General Services	NASA, JPL	Multicapability robotics to support or enable missions	UAV type suppliers, mining technology suppliers, robotics suppliers, e.g. MDA Robotics, Northrop Grumman, iRobot	Multicapability robotics to support or enable missions
S.4	Legal Advice for Entrepreneurs	Agency lawyers	Government astronauts, procurement advice & services, regulatory authorities, legislators, agency employees, and contractors	Lawyers, space law specialists, consultants, lobbyists. Ex: PwC.	Entrepreneurs, commercial astronauts, ITAR and other export control advice.
S.5	Legal Advice for Legislators				
S.6	Knowledge Store on the Earth	Agencies, research institutes	Mission planning, engineering	Google, journals,	Mission planning, engineering
S.7	Knowledge Store on the Moon	Data	Maps, medical info, manuals, Moon data repository, etc.	Journals, www.user-service-manuals.com, Google,	Maps, medical info, manuals, Moon data repository, etc.
S.8	Systems Engineering & Administrative Documentation	None	Outsourcing of paperwork, optimization of workflow	Accenture, other consultancies	Outsourcing of paperwork, optimization of workflow
S.9	Development and Accreditation of Industry Standards	NIST	NASA, military	ASTM, UL, IEEE, ANSI, EIA	Any commercial space vendor
S.10	Data and Services	Deep Space Network, TDRS, Air Force Ground Stations	NASA, NOAA, Military, Intelligence	IntelSat, Raytheon, Northrop Grumman, Lockheed, Loral	Commercial Sub-orbital, commercial satellite providers

S.11	Spectrum Management and Regulation	Statutory/regulatory bodies, e.g. Australian Communications & Media Authority, FCC	Space operators	Prime contractors, small consulting companies (Loktar Systems)	Google X prize competitors, sub-orbital providers, Satellite operators and hardware manufacturers
S.12	Insurance	Military, Coast Guard	NASA, Military, Intelligence	Lloyd's of London, Medjet	Sub-orbital flight providers, Global X-prize participants
S.13	Space Traffic Management, Navigational Systems	FAA, GPS, Glonass	Orbital and surface operations	Air traffic control companies, Galileo, Garmin, Tom-Tom, ground based radio-navigation systems	Orbital and surface operations
S.14	Cartographic Data	Raw data production	Surface operations, exploration and production	Google Maps, Spot Image, Infoterra, Space Imaging, etc. (overlaying information)	Surface operations, exploration and production
S.15	New Recruit Training				
S.16	Specialist Treatment of Astronauts, Preventative Medicine,	Deep Space Network, TDRS, Air Force Ground Stations	NASA, NOAA, military, intelligence	Wyle Labs (JSC PI on Health); NPS Pharmaceuticals (osteoporosis Shuttle experiments); Roche (make boniva, osteoporosis drug); GlaxoSmithKline (make boniva, osteoporosis drug)	Commercial sub-orbital, commercial satellite providers
S.17	Telemedicine				
S.18	Medical Equipment Supply				

Lunar Access Working Group Market Analysis

	Near-term Commercial Possibility	U.S. Government (USG) Supply	USG Demand	Private (non-USG) Supply	Private (non-USG) Demand
A.1	Small Lunar Landers	Case studies: Cubesats; NASA Ames Small Spacecraft Division; Mars Pathfinder; DARPA grand challenge; NASA/X PRIZE Lunar Lander Challenge; Air Force STP/responsive space	NASA: Science missions, robotic missions	Google Lunar X PRIZE contenders; FedEx to deliver small packages to lunar outposts; companies with previous space propulsion experience; companies with satellite experience (e.g., Surrey, Iridium, Teledesic); companies with Mars lander experience; Lunar Lander Challenge companies; universities	Precursor/prospector for businesses; entertainment (rovers, etc.); navigation beacons for human-rated vehicles; small science payloads; other
A.2	Multiple Lander "ESPA Ring"	None	NASA science and robotic missions	FedEx to deliver small packages to lunar outposts	All Google X prize contenders, small science payloads, other governments, pre-cursor/prospector for businesses, entertainment (rovers, etc.)

A.3	Secondary Payload ETO Launch Vehicle Adapters	None	NASA	Launch vehicle providers (Atlas, Delta, Ariane 5, etc.), ESPA ring developers (CSA Engineering, Inc.)	Small satellite developers, universities, other governments, precursor/prospector for businesses
A.4	Unmanned Space Tug Demo Mission	NASA, Department of Defense, DARPA with seed/development/qualification funds.	Department of Defense, NASA; (deliveries to ISS or other space stations), de-orbiting spacecraft	ATK/Universities/Orbital Recovery/Andrews Space/Aerojet currently involved in developing required technologies	Bigelow space habitats, on-orbit propellant depots, de-orbiting spacecraft, organizations interested in cleaning up space junk
A.5	Unmanned Space Ferry Demo Mission	NASA, Department of Defense, with seed, development, qualification funds	NASA, Department of Defense	Universities, orbital recovery, Andrews Space, Aerojet currently involved in developing required technologies	Orbit insertion for GEO communication satellites, orbit disposal, recovery services
A.6	Automated Rendezvous and Docking Demo On-Orbit	None	NASA (ISS), Department of Defense	Sensor manufacturers, spacecraft developers (Bigelow), auto industry, automation industry, submarine and aircraft manufacturers.	None
A.7	Commercial Orbital Test Services	NASA	None	Integration company, launch service provider	None
A.8	Orbital Propellant Depot Demo Mission	Operators: NASA	NASA (EDS "topping", reusable delivery of lunar probes/landers, large-scale deep-space probes such as JIMO, etc) , Department of Defense (GEO sat delivery)	Operators: Large aerospace primes (Dallas Bienhoff's group at Boeing Advanced Systems, ULA, etc.), Bigelow Aerospace , other entrepreneurial actors Suppliers: existing commercial or international launch vehicle providers (ULA, SeaLaunch, Russian providers, etc.), NASA launchers (Ares I/V) Future launch vehicles (RLVs, AirLaunch, SpaceX), University of Memphis, Lockheed Martin/ Centaur, Zero Boiloff Technologies.	Space Adventures (Soyuz-around-the-moon trans-lunar tourism), Bigelow Aerospace (expressed interest in trans-lunar tourism, L1 stations, and lunar landers), Comsat delivery companies (Boeing, SpaceX, Lockheed Martin), International Space Programs (India, Russia, ESA, Japan, China), Interplanetary transfer stages for nanosatellites (government or university funded projects).

Lunar Environmental Utilization Working Group Market Analysis					
	Near-term Commercial Possibility	US Govt (USG) Supply	USG Demand	Private (non-USG) Supply	Private (non-USG) Demand
E.1	Lunar Map Production	NASA, USGS, other collectors of original data	NASA, DOE, searching for best landing sites	Other space agencies, Google, Yahoo, Microsoft, any software company that has mapping expertise	Other space agencies, any lunar entrepreneurial venture or user of GIS software, educational institutions, research institutes (e.g. SOWRI, DR), exploration of resources
E.2	Ruggedized Instrumentation, Tools, and Equipment	NASA, NOAA, USGS	NASA, NOAA, USGS, DOE	DeltaNu, ASD inc, Rockhound-Raman	Educational institutions, research institutions, oil/gas companies, mining companies
E.3	Sale of Lunar Dust	NASA	None identified	Goolge Lunar X PRIZE teams, a specialized dust-selling entrepreneur	Average person
E.4	Dust Mitigation Techniques	Undeveloped	Undeveloped	Undeveloped	Undeveloped
E.5	Terrestrial Bioremediation Techniques (Medicine)	Undeveloped	Undeveloped	Undeveloped	Undeveloped

Cultural Industries Working Group Market Analysis					
	Near-Term Commercial Possibility	US Govt (USG) Supply	USG Demand	Private (non-USG) Supply	Private (non-USG) Demand
IMMERSIVE EXPERIENCES					
C.1	Parabolic Flight Agreements (Super Hero Experience)	None	None	Zero G, Virgin Galactic, entertainment industry, comic book companies, Anime	General public
C.2	Remote Controlled Rovers in Extreme Locations on Earth	MER, etc	NASA	Google Lunar X PRIZE teams, iRobot's Packrobot	General public, movie production, game manufacturers
C.3	Self-Contained Battlerooms to Control Robots (Robotic Video Games)	None	DHS	Video game companies, virtual reality developers	General public, entertainment companies
C.4	Refine existing experiential devices	None	DHS	Video game companies, virtual reality developers	Entertainment companies, general public
C.5	Space-Themed Sports Parks with Space-Themed Products, Boards, and U-Ramps	None	None	Sporting good companies, theme park developers, olympics	Sporting enthusiasts
C.6	Wedding Ceremonies / Honeymoons in Space	NASA/ ROSCOSMOS	None	Zero G, Virgin Galactic, more potential providers	General public
REALITY TELEVISION/ GAME SHOWS					
C.7	Tuff'Nuff'forSpace (Reality Game Show)	NASA, ROSCOSMOS	None	Virgin Galactic, Devon Island, NASTAR training facility, Entertainment Industry	Entertainment Industry, General Public

C.8	Lottery for Parabolic Flights and Suborbital Rides	NASA/ ROS-COSMOS	None	Virgin Galactic, more potential providers	General Public
SPACE PRODUCTS					
C.9	Guidebook for the Moon (Lonely Moon)	None	None	Publishing industry	Adventure tourists, general public
C.10	Using Lunar Rocks or Dust, Meteorites, Crystals, etc. (Space Jewelry)	None	None	Artists, jewelers, contractor to devel-op and operate the technology for the growth chamber; an orbital rendezvous company to retrieve the gems.	General public
C.11	Collection of Materi-als for Lunar Data Archiving	None	None	Potential winners of Google Lunar X-Prize	General Public
C.12	Commemorative Videos	None	None	Zero G, Virgin Ga-lactic, more potential providers	General public
C.13	Space-Themed Lug-gage	NASA	None	Luggage manufac-turers	General public
ARTS AND ENTERTAINMENT					
C.14	Terrestrial Perfor-mances (Cirque de Lune)	None	None	Cirque du Soliel, other acrobatic troupes, private investors	General public
C.15	Art from Discarded Space Vehicles and Materials	NASA	NASA	Artists	General public
C.16	Lunar Arts Endow-ment to Fund “Artist in Space” Program	NASA/ ROS-COSMOS	NASA	Artists, Virgin Galac-tic, other potential providers	Artists, General Public
C.17	Space-Themed Fash-ion Shows	None	None	Fashion designers, project runway	General Public
OUTREACH					
C.18	Technical and Media Public Relations Teams	None	NASA	Public relations firms, professional journalists	Private space industries, any industry with space venture
C.19	Educational Materials	NASA	NASA	Private space firms	Schools, teachers, general public

Appendix C

Infrastructure, Utilities, and Consumables Working Group Identified Risks		
Opportunity Code	**Near-Term Commercial Possibility**	**Risks**
	TRANSPORTATION	
I.1	Terrestrial Rover Sandboxes	Potential human involvement to "reset" the sandbox (needs automated solution)
I.2	Exploration Rovers	High launch costs
I.3	Tele-Operated Repair Robots	Technical complexity (advanced dexterity and manipulators)
I.4	Small-scale People and Cargo Movement Capability	Fairly niche market
		High cost of production
		Technical expertise needed (engineering/programming)
I.5	Surface Topography Mapping	Requires orbiting satellites to enable surface mapping and/or surveying
I.6	Development of Fuel Depot Systems	Requires significant demand before capital will be invested
		Poor foresight will eliminate capability and common interfaces for spacecraft
I.7	Orbital Hotels in LEO	Need access to launch vehicles
		Technically complex
		Orbital debris
		Safety
		Sharing between government and commercial entities
I.8	Electric Car Stations	Compatibility/interface with future lunar space systems
		International standards for commonality
I.9	Stations for Dedicated Network of Terrestrial Rovers	Financial/development risk
I.10	Terrestrial Launch & Landing Facilities	Large up-front cost
		Must follow government regulations
		Liability risks
	HABITABILITY	
I.11	Human Factors	
I.12	Food Grown in Habitat	Financial
I.13	Storage/Cargo Systems	
I.14	Delivery from Earth, Distribution, and Storage of Chemical Consumables	
I.15	Delivery from Earth, Distribution, and Storage of Water	
I.16	Ionic Membrane, CO2 Control Systems, Mechanical Filtering of Dust	
I.17	Piping, Plumbing, External/ Internal Waste Recycling	
I.18	Space Suits	
I.19	Thermal Control Systems	Financial
I.20	General Equipment	
	POWER, COMMUNICATIONS, AND NAVIGATION	
I.21	Solar Power Generation/ Cryogenic Storage	Material availability, cost of research & development

I.22	Private Expansion of DSN	Use of private funds to provide public infrastructure.
		Lack of custom, construction delays, inability to find sufficient qualified staff, cost overruns.
		Construction/operation delays beyond their control putting missions at risk OR loss of data from missions
I.23	Lunar Navigation via High-Resolution Images and Pattern-Recognition Advancements	Application of pattern-recognition to navigation is relatively new.
		Availability of lunar map with sufficient resolution.
	FACILITIES	
I.24	Radiation Testing	Financial/development risk
I.25	Thermal Testing	Financial/development risk
I.26	Microgravity Testing	Financial/development risk
I.27	Vacuum Testing	Financial/development risk
I.28	Dust Testing	Financial/development risk
I.29	Vibration Testing	Financial/development risk
I.30	Facility Brokering	
I.31	Orbital Habitats	Research may be perceived as interfering with government operations on station.
I.32	ISS Centrifuge	Huge financial endeavor to pick up cost of developing attachment & launching
I.33	High Strength-to-Weight Materials	Minimal risk, good application to low cost Earth-based construction.
I.34	Memory Shape Materials	Minimal risk, good application to low cost Earth-based construction.
I.35	Radiation Protection Materials	
I.36	Lightweight Tools	Minimal risk
I.37	Simple Construction Rovers	Developmental/financial risk
I.38	Regolith Excavation/Mass-moving	Planetary protection groups may oppose defacing the surface of the Moon.
I.39	Sampling and Drilling	Planetary protection groups may oppose defacing the surface of the Moon.
I.40	Dry Mining	Planetary protection groups may oppose defacing the surface of the Moon.

Services Working Group Identified Risks

	Near-Term Commercial Possibility	Risks
S.1	Space Debris Tracking and Removal	safe disposal methods, transportation
S.2	Multi-Capability Robotics, General Services	
S.3	Legal Advice for Entrepreneurs	
S.4	Legal Advice for Legislators	
S.5	Development of a Framework	
S.6	Knowledge Store – on the Earth	
S.7	Knowledge Store - on the Moon	Data loss, easy competition failure to adapt standards, closed access
S.8	Systems Engineering & Administrative Documentation	
S.9	Development and Accreditation of Industry Standards	Industry wide failure to adopt standards
S.10	Data and Services	Security breaches, data loss, space weather
S.11	Spectrum Management and Regulation	Accidental or subversive use of controlled spectrum, terrorism, space weather
S.12	Insurance	Accidents, terrorism,
S.13	Space Traffic Management, Navigational Systems	Liability associated with bad navigation
S.14	Cartographic Data	Liability associated with incorrect data

S.15	New Recruit Training	
S.16	Specialist Treatment of Astronauts, Preventative Medicine,	Launch vehicle failure (from the Earth, from the Moon, transfer orbit), death or injury of astronauts. Cultural risks: cultural barriers including languages, religion and national beliefs Technological risks: maturity and evolution of technology as new products enter the market and supply of parts that become obsolete
S.17	Telemedicine	
S.18	Medical Equipment Supply	
Lunar Access Working Group Identified Risks		
	Near-Term Commercial Possibility	**Risks**
A.1	Small Lunar Landers	High fixed and marginal costs
		Reliability
		Lack of precedent by commercial entities in this technology
		Bored with the moon (insufficient political/social interest)
		Lack of legal precedent for commercial lenders
A.2	Multiple Lander “ESPA ring”	High fixed and marginal costs
		Reliability
		Lack of precedent
		Insufficient political/social interest
A.3	Secondary Payload Earth-to-Orbit (ETO) Launch Vehicle Adapters	Reliability
		Lack of historical launches to in spire confidence
		Accommodating ESPA payload with primary payload(s)
		Generic ESPA ring with more increased cost for more customized ring
		Manifesting particular subsystems on ESPA ring (limited impact on primary payload)
		Competition with other launch vehicles for smaller satellites
		Getting secondary launch rings on other launch vehicles besides Atlas V, Delta IV, Ariane 5 (such as Minotaur, Falcon 1/9, etc.)
A.4	Unmanned Spacecraft Tug Demo Mission	Industry/NASA acceptance of the technology
		Qualification of the technology
		Implementation and acceptance of standardized interfaces
		Refilling the tug’s fuel tank
		Making the technology applicable for a wide range of applications
		Making the technology as simple and robust as possible
		Ensuring adequate spacecraft lifetime (radiation, eclipses, power, propulsion, micro meteoroid impacts are all issues)
A.5	Unmanned Space Ferry Demo Mission	Industry and government acceptance of the technology and approach (this is a new way of doing business in space)
		Automated rendezvous and docking technology
		Implementation of standards (especially for docking)
		Ensuring adequate spacecraft lifetime (radiation and micro meteoroid impact survivability require more research to retire risk)
		Handling a variety of customer spacecraft requirements and configurations
		Making the trip time palatable to customers (~90d for GEO communication satellites).
A.6	Automated Rendezvous and Docking Demo On-Orbit	Adoption by industry and government agencies
		Technical challenges – integration, backwards compatibility, system reliability
		Tradeoff between design flexibility and standardization/interoperability

A.7	Commercial Orbital Test Services	Market conditions – will a company respond to the need?
		Perceptions for what each TRL is and what it enables. Can the TRL's be re-examined and further codified to define what they allow to be utilized on operational missions?
		Cheaper access to Earth orbit needs to be in place
		Telemetry infrastructure – the test bed will need a way to get telemetry to the ground, through ground stations or orbital assets such as TDRSS or commercial satellites.
A.8	Orbital Propellant Depots Demo Mission	Chicken-and-egg issues. Because a propellant depot doesn't yet exist, no customers that need propellant depots exist. It takes a finite amount of time from when the capability exists for suppliers and customers to adapt the new technology.
		Technology issues. There are several microgravity fluid management technologies that are at low TRL levels, and need maturation (long-term cryogenic storage; cryo fluid settling/transfer; cryo fluid handling, mass measurement, etc).
Lunar Environmental Utilization Working Group Identified Risks		
	Near-Term Commercial Possibility	**Risks**
E.1	Lunar Map Production	Willingness of other space fairing nations to share data as openly as US
E.2	Ruggedized Instrumentation, Tools, and Equipment	
E.3	Sale of Lunar Dust	Rarity of samples not allowing commercialization, therefore need large supply
E.4	Dust Mitigation Techniques	
E.5	Terrestrial Bioremediation Techniques (Medicine)	
Cultural Industries Working Group Identified Risks		
	Near-Term Commercial Possibility	**Risks**
IMMERSIVE EXPERIENCES		
C.1	Parabolic Flight Agreements (Super Hero Experience)	Risk of injury to the participants
C.2	Remote Controlled Rovers in Extreme Locations on Earth	Risk of damage to rover due to user action
C.3	Self-Contained Battlerooms to Control Robots (Robotic Video Games)	High development cost; high user cost
C.4	High-definition Sensory Media Experiences	High development cost, high user cost
C.5	Space-Themed Sports Parks with Space-Themed Products, Boards, and U-Ramps	Risk of injury to participants
C.6	Wedding Ceremonies/ Honeymoons in Space	High cost leads to limited market
REALITY TELEVISION/ GAME SHOWS		
C.7	Tuff'Nuff'forSpace (Reality Game Show)	Support from entertainment industry; risk of injury to the participants
C.8	Lottery for Parabolic Flights and Suborbital Rides	Financial
SPACE PRODUCTS		
C.9	Guidebook for the Moon (Lonely Moon)	Partnering with the publisher willing to expand their current established series to include the moon as a new volume
C.10	Using Lunar Rocks or Dust, Meteorites, Crystals, etc. (Space Jewelry)	Very niche opportunity

C.11	Collection of Materials for Lunar Data Archiving	High launch costs for payload delivery, developing long term data storage medium
C.12	Commemorative Videos (Professional Editing and Documentation of Space Travel Experiences)	Limited market
C.13	Space-Themed Luggage, Using Space Materials	High cost of luggage limits market
ARTS AND ENTERTAINMENT		
C.14	Terrestrial Performances (Cirque de Lune)	Financial agreement working with NASA
C.15	Art from Discarded Space Vehicles and Materials	
C.16	Lunar Arts Endowment to Fund "Artist in Space" Program	High cost of the program
C.17	Space-Themed Fashion Shows	
OUTREACH		
C.18	Public Relations Agency	Start-up capital, working with government Public Affairs Office
C.19	Educational Materials	

Policy recommendations

The following are policy recommendations proposed by the Services working group:

Reform ITAR and international engagement policy to enable and encourage commercial development.

- Implement an open source development approach.
- Provide monetary incentives for agency employees to select service provides based on those that save time and money.
- Develop a commercial legal framework to support commercial operations with specific focus on property rights and land use.
- Further clarify management of intellectual property generated off-Earth.
- Create a Lunar environment protection policy.

The following are policy recommendations proposed by the Lunar Access working group:

- Support designs of a spectrum of engines.
- Offer affirmation with a schedule of future markets.
- Make test facilities and programs available.
- Issue statement of need.
- Standardize payload interface.
- Implement a government-funded demonstration mission.
- Make demo flights available (test missions).
- Develop a space-debris policy, especially for debris that is already there.
- Include orbital debris in international discussions, include discussions of who pays for de-orbit, who is liable for damages.
- Define a policy statement of need; NASA may need to be a lead customer.
- Maintain an open architecture paradigm during all phases of Lunar exploration.
- Fund and enable the creation of an international group to develop standards for space-docking interfaces.
- Implement hardware and software per standards given previously.
- Implement a market guarantee.
- Implement hardware on a multinational basis.
- Sponsor prizes for related technologies or services; Centennial Challenges has proposed

prizes for long-duration cryogenic storage; the company could also offer a prize for development and demonstration of a propellant transfer interface, or demonstration of vehicle-to-vehicle cryogenic propellant transfer.

- Renew some of the technology investment that was originally planned as part of the Vision for Space Exploration in the form of the H&RT research program.
- Make demo flights available (test missions).
- Organize a standards committee to settle on the standard interface characteristics.
- Set contract language to protect the intellectual property rights of the companies that develop enabling technologies for the testing service while maintaining the open standards of the payload interface with the bus.

Following are policy recommendations proposed by the Lunar Environment Utilization working group:

- Mandate timely release of data from all Lunar exploration agencies (NASA, ESA, JAXA, etc.).
- Perform accurate Lunar referencing on a mission-by-mission basis, for example, by using beacons and triangulation methods for Lunar mapping.
- Provide a timeline for “Return to the Moon” and the related actual need of instruments to support this.

The following are policy recommendations proposed by the Cultural Industries working group:

- Open government facilities to outside research and development use.
- Support partnerships and information exchange between the publisher and NASA, as well as future Lunar tourism companies.
- Be willing to work with the media and outreach on behalf of the companies and clients.

Appendix D

Framework and Implementation of the NGEC-2 Mixed Reality Broadcast

Andrew Hoppin, NASA Ames Research Center, CA, andrew.hoppin@gmail.com
Paul G. Graham, Alpine Systems Engineering Ltd, MI, paul@alpine-engineering.us
Troy McConaghy, Waterloo, Ontario, Canada, troy.mcconaghy@gmail.com
Paradox Olbers, NASA CoLab Sim, Second Life & Boston, MA, paradox.olbers@gmail.com
Greg Pitzer, NASA Ames Digital Learning Network, gregory.e.pitzer@nasa.gov
Stephanie Smith, NASA JSC Learning Technologies, TX, stephanie.l.smith@nasa.gov
Sanjoy Som, University of Washington, Seattle, WA, sanjoy@u.washington.edu
Cynthia Stagner, South Valley Media Group, CA cynthia@stagner.com

Introduction
This paper details a mixed reality broadcast produced by an eclectic team of computer professionals during the 2008 NASA Next Generation Explorers Conference (NGEC) held at the NASA Ames Research Center. The term "mixed reality" refers to the merging of real and virtual worlds to create a shared environment where people or objects can interact in real-time.

Mixed reality (MR) is created with computer networking and graphics technologies to seamlessly combine and represent real and virtual spaces for people who are not co-located. MR is typically event-based so people can share information, activities, discussion and ideas. The NGEC mixed reality event was specifically a merging of the real-world NGEC meeting room at the Ames Research Center and the Second Life NASA CoLab simulation. Second Life (SL) is a 3D immersive, synthetic environment or "virtual world" inhabited by millions of avatars engaged in business, learning or social activities.

Figure 1: Simplified representation of a "virtuality continuum". - Milgram

The NGEC-2 conference was held February 12-15, 2008 at the NASA Ames Research Center. The conference was attended by emerging global space leaders to design the future of space exploration and focused on "Entrepreneurial Opportunities in Lunar Development". To connect with a broader audience of those who could not travel to Ames, the event was broadcast via a real-time video/audio stream into the SL environment. The SL avatar participants attended the presentations via video and contributed to the working group sessions using video, text chat and email. SL attendees were able to ask questions and receive answers from the Ames speakers and participants. This paper details how the event was planned and implemented using one of the two broadcast solutions that were pieced together. It also contains a glimpse of user experiences and conclusions.

Implementation

This broadcast project began as a "wouldn't it be great" suggestion at the weekly SL NASA CoLab meeting. A small group of people agreed to take on the challenge with the knowledge that it would be an all-volunteer effort working in different locations with no financial resources and very little time. From start to broadcast there were 4 working days to organize a team, assess the technical requirements and implement a solution.

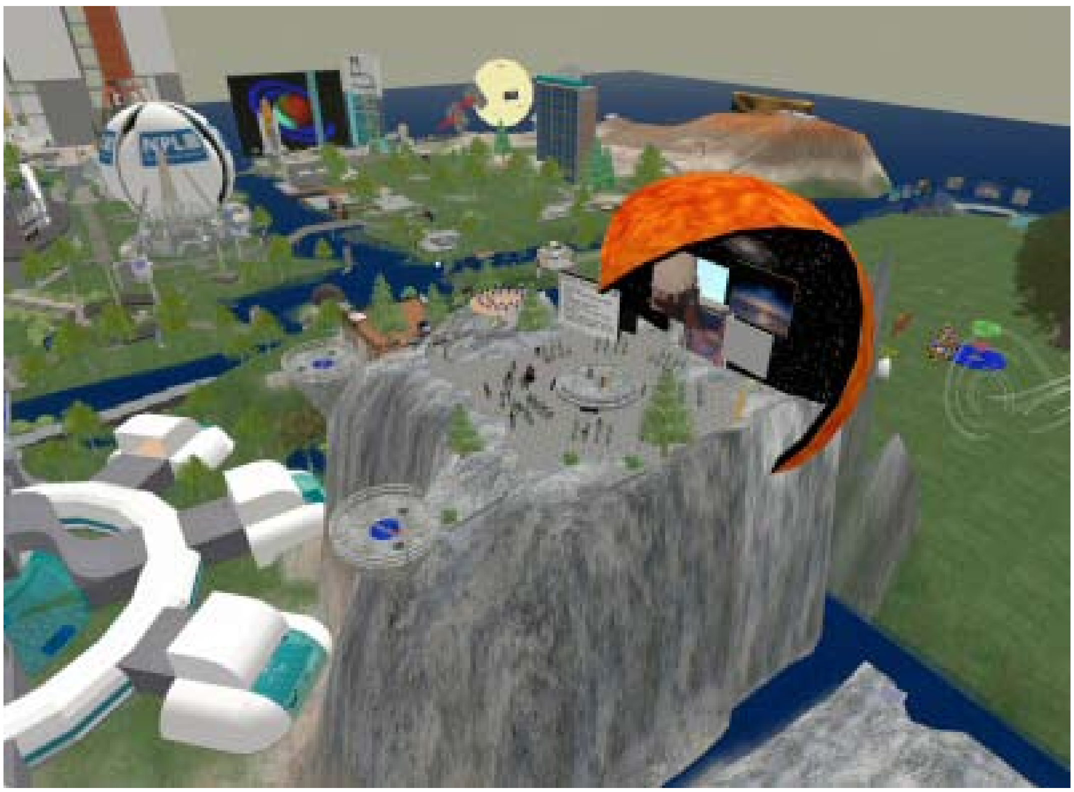
The team took shape as a broad assemblage of people from eastern Canada, Texas, Northern California and Second Life. Technical broadcasting expertise ranged from professionals to rookies. Second Life expertise ranged from expert to beginner. All SL organizers had land management/estate permissions to setup, run and manage the event inworld . Coordination across time zones and different locations took place through numerous email, phone and Second Life conversations.

The basic sequence for getting a video/audio stream into Second Life is: 1) configure and setup the hardware and software at the broadcast location, 2) capture the video/audio as a digital stream on location, 3) encode the stream 4) give the encoded stream via the network to a streamhoster, 5) access the streamhoster account from Second Life. The team had to find the hardware and software to capture and encode the stream as well as locate a streamhoster to broadcast the stream into SL.

The main venue for the event, the Ames Conference Center provided basic AV equipment, microphones and limited network access for the team's use. The conference center does not provide computers for events so it was the team's responsibility to find a suitable, powerful computer loaded with the correct software to capture and broadcast the event. A mobile, networked Polycom broadcast system was discovered at the conference center that might also provide a solution for broadcasting the event. The team took the approach of working both options, a stand-alone computer and the Polycom system, to see which one was viable and could be made to work in the amount of time available.

The Second Life venue used for the NGEC event is known as the Sun Amphitheater. It is atop the highest mountain on the NASA Colab simulation or "island". It is an open-air venue with two circles of chairs surrounding a central raised stage. On the south edge of the venue, there is a large hollowed-out sphere with a star texture on the inside and a sun texture on the outside. Screens float in the air facing the stage from the south edge, inside the sun sphere. The venue, including the ascending mountains, was mostly built by a NASA avatar in under a week after the sim came online in late 2006. It wasn't purpose-built for the NGEC event as is frequently the case in Second Life. In fact, it was created in early 2007 and used for previous events, including the keynote speech given by NASA Ames' Director General (Simon) Pete Worden to the International Space Development Conference on May 26, 2007. For that public event, the venue held the maximum 68 avatars.

A large challenge for broadcasting the stream into SL was securing a Quicktime streamhoster on short notice. A Quicktime stream was a requirement since that is the accepted streaming format in Second Life. The NASA CoLab is part of a loose conglomeration of science agencies and organizations in Second Life called the SciLands. Another SciLands member is the National Oceanographic and Atmospheric Administration (NOAA) which owns a streamhoster account that can be used by the entire group. After numerous rounds of email tag we were able to connect and NOAA SL manager Eric Hackshaven graciously made the streamhoster account available to the CoLab for this event. To receive the Quicktime stream in SL, the managing avatar(s) had parcel permissions to load the media stream and create objects. Other inworld preparations at the SL sim included upgrading the viewing screen and texturing it with a media texture, providing conference overview and schedule information panels and real-time updates to the event board. With little notice, SL personnel were given powerpoint presentations to upload and format for viewing inworld during various talks and presentations.



http://www.flickr.com/photos/22159806@N07/2263329700/sizes/o/in/pool-638334@N24/

It's important to understand that the starting point of the project was solely an idea to broadcast the NGEC event into Second Life. The team had never met before, was not fully co-located, had no budget and very little time. The availability of hardware, software and broadcast equipment was unknown. The configuration and support system within the conference room was also unknown. The team had a good amount of experience in specific areas but little experience with this set of variables for a total solution. The first task was to get a broadcast system running. Since the conference center does not supply computer equipment, the team had to secure a computer powerful enough to broadcast the event. It was decided to piece together the broadcast system from contacts within the Ames community. The inhouse

Polycom broadcast system was a chance discovery and potentially a viable solution for broadcasting also. The team set to work on both solution ideas.

To get the stand-alone solution going we requested a computer from ODIN, the IT contractor at Ames. After a day of negotiating we could not procure a computer from them. The network administrator assigned to the conference room was able to find a Mac G5 Tower which we gratefully accepted and setup. The Mac OS had to be upgraded which took quite a bit of time. The encoding software Wirecast was also installed. There was a substantial time sink in getting the machine upgraded. Once the machine was upgraded and ready to go it was discovered that additional firewall permissions were needed. The team worked all the contacts they could think of to secure network access which was finally granted Monday night, the evening before the conference began. Once the firewall was lifted on the correct ports we were able to plug in, turn on and go. We were able to get video streamed immediately but it took some time to configure the audio. We knew that the NOAA streamhoster account we borrowed was preconfigured for Wirecast so we installed a demo copy of Wirecast encoder. The rationale for using the demo Wirecast was the preset streamhoster configuration and it was free. It turns out that the demo copy of Wirecast would not broadcast audio on the codec required by the streamhoster. We switched the encoder to the free Apple Broadcaster, ran the audio with FireWire, reconfigured the streamhoster and finally got both video and audio.

The mobile Polycom system runs a video/audio feed from the Ames conference room to a broadcast studio via H.323 connection, ie videoconferencing. The feed was sent to the streamhoster in two ways. The videoconference unit works with an WindowsXP system which ran with the demo version of Wirecast and also with a Mac OS 10.4 system running Apple Broadcaster. Both the Wirecast and Broadcaster solutions sent the Quicktime stream to the NOAA streamhoster account. Again, the demo copy of Wirecast did not produce an audio signal and the encoding software was switched to Apple Broadcaster. The Second Life venue was set to load the media stream from the hoster and given to each individual avatar upon request. The streamhoster account accomodates 100 streams. The Second Life sim accomodates 50-68 avatars at any given time so there were plenty of streams available. The Apple Broadcaster was a nice solution because it’s free and does the basics very well. Wirecast costs about $300 for a license, but adds a lot of features to make the broadcast more “professional” such as adding a logo, subtitles and other graphics. You can set up a shot in advance before it goes live and you can monitor both the live video and audio feed.

The final broadcast solution the team used was the stand-alone computer system that was a combination of equipment from the conference center, NGEC staff and our camera technician’s personal inventory. The Polycom system could have also been used but since that system included one more hop for the stream to make on it’s way to Second Life it was decided to use the stand-alone computer to reduce latency and streamline the data transfer. Within 4 days the team came up with two viable solutions to broadcast the event. In fact, in a stroke of synchronicity, both systems were running within minutes of each other the night before the conference. The tech team was on the phone, logged in to Second Life and broadcasting video to each other all at once. It was almost anti-climactic when the event started given the intensity of the preparations to broadcast. All told, the resources required to broadcast the NGEC event into Second Life included a broadband internet connection with firewall access on the right ports, a MAC G5 Tower, Apple Broadcaster, a Quicktime streaming server account, a video camera with a firewire port, a long firewire cable, headphones, microphones, a mixing board, a PA system, a camera tripod, a tripod dolly, mic stands, wireless microphones, microphone cables, support cables, various other camera support devices and lighting. It also required an additional PC with the latest Quicktime to monitor the SL session and a PC with an operator/avatar to upload and display powerpoint slides in SL. It's important to not run the monitoring and upload functions on the same computer as this causes lag and performance problems.

User Experiences
The team received many useful and interesting comments from attendees in the conference room and in Second Life. These comments appear in totality in Appendix A.

Many of the positive comments about the event indicated that this experimental collaboration in mixed reality is an innovative approach and has great potential for the future. It was deemed a very good way to share the large group presentations. Most people generally liked the interaction and the experience. Participants were glad the 3D virtual world was included. Negative technical comments concerned communication problems between the two groups due to lag and pace, the mixed voice and text speech modes and the lack of good microphone setups for the breakout group interaction. Negative comments about interacting with SL avatars centered on behavior and etiquette problems, unprofessional attire, follow through and avatars coming and going. Negative comments from the SL group indicated the avatars had no clue about expectations regarding their participation, little context of the requirements and no information about where the output of the conference was located. The SL avatars did not realize they were engaging in distracting behavior and would have liked the conference room attendees identified by name and area of expertise to provide context for their comments.

The attendees suggested many ways to improve this type of event. From the conference room technical suggestions were primarily about improving the audio channels between the groups. It was thought that an array of mics on each table would enable a more collaborative exchange. Skype was suggested as a means of voice interaction. Another person suggested that the audio be broadcast on loudspeakers. Comments about interactions suggested better conference etiquette and participation by invitation only. The audio for the SL participants was not as big an issue so suggestions focused on interactions between the groups and behavior in the SL environment. It was pointed out that the demographics of the audience could be better controlled through invitation, the posting of positively stated behavioral expectations would be helpful and that two sim managers should be on hand at any given time to facilitate the event and eject or ban any offending avatars.

Conclusions
The NASA CoLab sim logged 565 unique visitors and approximately 500 total hours visitation during the conference period. Daily avatar visits ranged from 167 to 228 unique visitors per day according to sensors located on the sim. The goal of bringing the NGEC event into Second Life so people in the real world and the SL virtual world could interact in real-time was accomplished. There were some technical issues with cables, microphones and stream reception that were fixed or worked around the first day and then the broadcast ran smoothly as the event progressed.

There is a strange occurrence in SL where some people see a video stream upside down and mirror image. To accomodate those people, two new screens were deployed on-the-fly: one right-side-up and one upside down. This didn't totally solve the problem, however, because new visitors would constantly say, "One screen is upside down!" There was discussion as to whether this is an SL bug or a conflict in different rendering protocols by the two main makers of graphics cards. The team is still investigating this. At one point during the event, it was noted that anyone could create (rez) objects in the parcel associated with the Sun Amphitheater. This allows people to cause problems by rezzing unwanted objects. Once the problem was discovered, the parcel settings were quickly changed so that only Space CoLab group members could rez objects there. It is advisable to have live audio contact between event managers in the real world and Second Life. The preferred method in Second Life is Skype.Wish list equipment on top of the essentials includes specialty teleconferencing microphones. An important part of the puzzle for a long term solution is the procurement of a Quicktime streaming server rather than having to rent or borrow space on somebody else's account. Other ways to improve future broadcast events include more lead time for planning and setup, better coordination between real world and virtual world planners plus dedicated hardware and software. From the technical perspective, the successes, problems and "how-to" lessons were well-learned by the team and will be codified in a separate document for others to use in planning their mixed reality events.

Perhaps as important as the nuts and bolts of the event is to understand the way the two groups interacted, their expectations of each other, what worked and what didn't work. The real-life group consisted of engineering professionals who gathered for a serious purpose and expected work products and deliverables from the meeting. The Second Life group appeared to be comprised of serious avatars who could not attend the conference in person, avatars who take an active interest in space and science issues, avatar passers-by and malicious avatars. SL avatars are frequently "outlandish" in dress, style, behavior and conversation which directly contrasted with the expectations of some group members gathered in real life. Attendees in the conference room who are also active in SL appeared more knowledgeable about and tolerant of SL cultural norms and mores. Additionally, SL avatars often engage in discussions of their SL client functionality or lack thereof and matters that are off topic. Even though SL has voice capability and 3rd party voice solutions like Skype exist, most of SL communications occur through text-based chat and this was a distraction to real life attendees who were watching the SL group on a projection screen.

Despite negative comments from the conference room about SL behavior most of the inworld avatars conducted themselves in an orderly fashion and exhibited courtesy throughout the event. For example, we found that most avatars preferred to sit in the seats on the north side of the SL venue. This is probably because the screens showing the live video were on the south side of the venue facing north. It is interesting because avatars can move their camera to look wherever they like, regardless of where their avatar is sitting. It's as though people didn't want to have their avatar sitting in a position that faced away from the screens because that would appear rude. User comments from the conference room mention the fact that the SL group did not contribute any input or products to the working group. SL user comments indicate that avatars were not able to contribute due to computer lag and the manner in which information requests were relayed. This illustrates the difficulty of managing unplanned, real-time activities between the two groups. It should be noted that SL avatars were not aware nor made aware of participatory requirements. Should an event similar to this be conducted in the future it would be useful to establish some compromise guidelines for each respective group so that behavioral expectations and responsibilities are reasonable within the scope of each environment.

References

Maya Realities http://www.mayarealities.com/

Milgram, P. and Kishino, A. F., *Taxonomy of Mixed Reality Visual Displays* IEICE Transactions on Information and Systems, E77-D(12), pp. 1321-1329, 1994.

NASA CoLab NGEC 2 flickr group http://www.flickr.com/groups/638334@N24/pool/

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
25-06-2008	Proceedings of a conference	February 12, 2008- February 15, 2008

4. TITLE AND SUBTITLE
Proceedings of the Next Generation Exploration Conference-2: Entrepreneurial Opportunities in Lunar Development

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Delia L. Santiago (Editor)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
018306.01.03.02

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA CoLab, NASA Ames Research Center, Moffett Field, CA 94035

8. PERFORMING ORGANIZATION REPORT NUMBER
A-080011

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration, Washington, D.C., 20546

10. SPONSORING/MONITOR'S ACRONYM(S)
NASA

11. SPONSORING/MONITORING REPORT NUMBER
NASA/CP-2008-214583

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified- UNLIMITED Distribution: Non-standard
Subject Category: 12, 23, 31, 83, 84, 91, 99
Availability: NASA CASI (301) 621-0390

13. SUPPLEMENTARY NOTES
Point of Contact: Delia Santiago, NASA CoLab Program Coordinator, Delia.L.Santiago@nasa.gov, NASA Ames Research Center, MS 17-1, Moffett Field, CA 94035. 650.604.1671

14. ABSTRACT
The Next Generation Exploration Conference-2 (NGEC-2) gathered over one hundred hand-selected future leaders in the space sector at NASA Ames Research Center on February 12-15, 2008, to gather information, exchange ideas, and spend a majority of their time in working groups creating an output which will offer global guidance on the topic of Entrepreneurial Opportunities in Lunar Development. This next generation of leaders, along with virtual contributors participating through NASA CoLab and Second Life, included engineers, scientists, and communication specialists from the US and abroad, both industry and government.

15. SUBJECT TERMS
NextGen, next generation, moon, lunar, entrepreneurial, commercial, CoLab, education, leadership

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19b. NAME OF RESPONSIBLE PERSON
U	U	U	UU		Robert Schingler
					19b. TELEPHONE NUMBER *(Include area code)* (650) 604-4790